Practical Water Treatment for Evaporative Condensers


Like most businesses, food processing plants and cold storage facilities are under continuous pressure to reduce costs and operate in a more environmentally responsible manner. As a major consumer of energy and water, the refrigeration systems can offer significant opportunities to meet these challenges. In facilities that use evaporative condensers as part of the refrigeration system, the water treatment program is often overlooked in the cost saving equation. Effective water treatment is necessary for reliable and efficient operation of refrigeration systems and to reduce the risks associated with waterborne pathogens. In many facilities, the water treatment program can be engineered to significantly improve energy and water efficiency. This article discusses practical recommendations to address the concerns associated with water treatment and reducing operational costs.

Importance of Water Treatment
An evaporative condenser is a type of cooling tower used to cool and condense hot refrigerant gas by circulating it through a condensing coil over which water is continuously sprayed. A portion of circulating water sprayed over the coil is evaporated, which removes the heat from the hot refrigerant gas causing it to condense into a liquid.

Evaporative condensers are widely used because they are more energy efficient than air cooled refrigeration systems. As compared to air cooled systems, evaporative condensers provide lower condensing temperatures and reduce compressor electricity requirements by up to 30%. However, to achieve these cost savings, an effective water treatment program is required to maintain maximum heat transfer efficiency, minimize water usage and protect the system from water related problems. By reducing energy and water use, effective water treatment also helps reduce the negative environmental impact and carbon dioxide emissions associated with a facility.

The water related problems that occur in an evaporative condenser can be broadly classified as:

- Scale Deposits
• Corrosion
• Microbiological Growth

Scale Deposits
Deposits are a serious concern in evaporative condensers. The continuous evaporation that occurs in the cooling process causes the dissolved solids in the circulating water to become increasingly concentrated. If the dissolved solids become overly concentrated, an adherent deposit termed scale will form on the condenser tubes. Condenser deposits may also include dust scrubbed from the air, corrosion by-products and microbiological matter (slime). Regardless of the source, the end result of deposits is reduced heat transfer efficiency, increased operating costs and equipment failure.

The payback associated with water treatment is directly related to maintaining clean condenser tubes. Deposits on the condensing coil surface significantly reduce the ability of an evaporative condenser to remove heat. For example, 1/32” of scale on the condenser tubes reduces its heat transfer capability by about 27%. In the absence of extra condensing capacity, scale build-up forces the compressor to work against higher head pressures. This in turn causes the compressor to use more energy and reduces refrigeration output. If the heat transfer loss is great enough, the compressor will shutdown due to high head pressure.

Figure 1 illustrates the impact of scaled condenser tubes on compressor energy requirements and output. It shows that 1/32” of scale on the condenser tubes can increase the energy costs by 7% and decrease the available refrigeration capacity (tons) by 1%. This reduction in energy efficiency will occur year round, but may go unnoticed until the capacity loss becomes apparent as the system operates on the hottest days.

An effective water treatment program that provides scale control directly translates into lower energy use and operating costs. Since burning fossil fuels to produce electricity is a major source of greenhouse gas emissions, saving energy also reduces carbon dioxide emissions. Based on U.S. national averages, each kWh reduction in electricity usage reduces carbon dioxide emissions by 1.55 lbs.
Corrosion

Corrosion is the destructive reaction of a metal, such as steel, copper or brass, with its immediate environment. Corrosion in water is usually an electrochemical reaction initiated by the presence of naturally occurring impurities in water or microbiological growth. The end result of corrosion is metal loss, which shortens system life and leads to equipment failure. Corrosion by-products like rust also contribute to deposit formation.

Evaporative condensers and condenser coils are primarily constructed of galvanized steel, which is prone to a unique corrosion phenomenon known as white rust. Unless the water chemistry is well-controlled during initial startup and commissioning, new galvanized steel tends to form a porous, non-protective deposit called white rust instead of the desired corrosion resistant film. Once started, white rust can be difficult to stop. White rust can also occur in older systems that continually operate at a high pH.

Microbiological Growth

Uncontrolled microbiological growth can cause major corrosion and deposit problems in evaporative condensers. Poor microbiological control also contributes to unsafe operating conditions by allowing Legionella bacteria, the cause of Legionnaires’ disease, to proliferate. The end result of poor microbiological control is reduced equipment life, increased operating costs, unexpected system failure and increased safety concerns.

Effective microbiological control generally requires the automatic, controlled addition of EPA registered biocides as part of the overall water management program. Because evaporative condensers have high evaporation rates and low water volumes, it is important to use biocides that act quickly. Mechanical systems employing hydrodynamic cavitation with filtration can also be effective for microbiological control.

Practical Water Treatment

The potential for corrosion, deposits and microbiological growth to occur in an evaporative condenser is a direct function of makeup water quality, system design and operation, and maintenance practices. Each water treatment program must be tailored to the specific makeup water chemistry at a plant and at a minimum consist of:

- Reliable Bleed Control
- Reliable Chemical Feed and Control
- Routine Onsite Maintenance

Reliable Bleed Control

As water evaporates from an evaporative condenser, dissolved solids are left behind and concentrate in the remaining water. To prevent the dissolved solids from over concentrating and forming deposits on the
condenser tubes, a portion of the circulating water must be sent to drain as bleed.

Reliable bleed control is very important. Too much bleed wastes water and increases chemical usage. Too little bleed can result in energy-robbing scale deposits. The amount of bleed required to prevent scale deposits is a direct function of the evaporation rate, the makeup water chemistry and chemical inhibitors being used. A water treatment professional evaluates these conditions to determine the optimum cycles of concentration for each system.

The cycles of concentration reflect the degree to which the dissolved solids in the makeup water are allowed to concentrate in the recirculating water of an evaporative system. The higher this ratio, the more the dissolved solids in the makeup water are being concentrated in the system water and the lower the bleed rate. The cycles of concentration can be estimated by dividing the conductivity of the circulating water by the conductivity of the makeup water.

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\text{Cycles of Concentration} = \frac{\text{Tower Water Conductivity}}{\text{Makeup Water Conductivity}}
\]

\[
\text{Bleed Rate} = \frac{\text{Evaporation Rate}}{\text{Cycles of Concentration} - 1}
\]

Conductivity is an easily measured property of water that is a direct function of the total dissolved solids (TDS) level. As evaporation occurs in the cooling tower, the conductivity of the circulating water rises. By measuring the conductivity of the makeup water and the conductivity of the cooling tower water, the cycles can be determined. For example, if the tower water has a conductivity of 1,000 uS and the makeup water has a conductivity of 200 uS, then the cooling tower is five times more concentrated than the makeup water and is said to be operating at five cycles of concentration (1,000/200 = 5).

Although evaporative cooling is very efficient, evaporative condensers require an astonishing amount of fresh water to operate. Approximately 1.53 gallons per hour of water is evaporated for each ton of refrigeration. This may not sound like a lot of water until you consider that a 500-ton refrigeration system operating at full load evaporates almost eight million gallons over the course of a year!

A key water treatment objective is to maintain the minimum bleed rate consistent with good deposit control. This is generally accomplished by adding chemicals to increase the solubility of scale-forming impurities and controlling the bleed rate so the target cycles of concentration is maintained. In some waters, mechanical systems employing hydrodynamic cavitation with filtration can also be effective for scale control without chemical addition. Because the bleed rate required to maintain the target cycles varies as the tower evaporation rate varies throughout the day and from season to season, an automatic bleed control system is necessary for good bleed control.
The environmental benefits associated with maximizing the tower cycles are significant. Table 1 shows that maintaining five cycles versus three cycles reduces water consumption by almost 17% and chemical requirements by 50%. However, insufficient bleed can result in waterside deposits that reduce efficiency and increase energy costs.

<table>
<thead>
<tr>
<th>Cycles</th>
<th>Bleed (GPD)</th>
<th>Makeup (GPD)</th>
<th>Annual Water Cost</th>
<th>% Reduction Water Cost</th>
<th>Inhibitor (lb/day)</th>
<th>Annual Inhibitor Cost</th>
<th>% Reduction Inhibitor Cost</th>
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<tr>
<td>3</td>
<td>10,800</td>
<td>32,400</td>
<td>$59,130</td>
<td>Base Line</td>
<td>10.8</td>
<td>$15,768</td>
<td>Base Line</td>
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<td>7,200</td>
<td>28,800</td>
<td>$52,560</td>
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<td>7.2</td>
<td>$10,512</td>
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<td>5</td>
<td>5,400</td>
<td>27,000</td>
<td>$49,275</td>
<td>16.7%</td>
<td>5.4</td>
<td>$7,884</td>
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<td>$43,800</td>
<td>25.9%</td>
<td>2.4</td>
<td>$3,504</td>
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Based on 500-Ton Refrigeration Load Operating 24 Hours/Day, 365 Days/Year, 21,600 GPD Evaporation
Water Cost = $5.00/1,000 Gallons, Inhibitor Dosage = 120 ppm, Inhibitor Cost = $4.00/lb

Table 1 - Cycles of Concentration vs. Water and Chemical Requirements

Reliable Chemical Feed and Control
The addition of chemical inhibitors and biocides allows high cycles to be maintained without efficiency losses and other problems. However, even the best water treatment chemicals will not provide good protection if they are improperly applied. Overfeeding water treatment chemicals is wasteful while underfeed can result in corrosion, deposits and microbiological growth problems. Automatic water treatment controllers are available to precisely apply treatment chemicals without overfeed.

Advanced data logging water treatment controllers are also available to automatically monitor and log key treatment parameters including water use. These controllers can interface with automation systems and the Internet to enable high-performance water treatment programs. They can warn personnel when upset conditions occur so minor concerns don’t turn into major waterside problems. They allow remote access to controller history and settings. Data management and analysis can also be used to help optimize results and reduce costs.

Common Sump Makeup Systems
Ammonia refrigeration systems often consist of multiple evaporative condensers located in clusters. Traditionally, a chemical feed and control system is installed on each evaporative condenser. There are several problems with this arrangement. It requires a separate water treatment controller and multiple chemical feed pumps for each condenser. The flow assembly used for chemical injection and bleed often stops up because it depends on flow from the low head condenser pumps. Each treated
system has to be tested and monitored separately, which is time consuming. It’s a complicated arrangement that can make effective water treatment difficult.

In plants with multiple evaporative condensers located in clusters, installation of a common sump makeup system will greatly simplify water treatment requirements. A typical common sump makeup system uses an open polypropylene sump with a circulating pump that is sized to supply all of the makeup water for all condensers plus continuously circulate water back to the central sump. Makeup water addition is controlled by a liquid level control installed on the sump. A water meter is typically installed to measure makeup water usage and control the amount of scale and corrosion inhibitor going into the system. The bleed valve is installed on the common return water line from the evaporative condensers. Since the water in all condensers is common, a single high-end water treatment controller can be used to control bleed and chemical feed.

Practical Onsite Maintenance
Routine onsite maintenance is an important part of any water treatment program. Regardless of how much the water treatment program is automated or how often the water treatment consultant services a facility, an in-plant monitoring program is necessary to prevent minor concerns from developing into major problems. Here are some practical steps to provide maximum benefit with a minimal investment of time:

1. Check water treatment controller readout for high/low conductivity reading daily. If conductivity is significantly below set point (low), check for leaking bleed valve or high water level in tower sump. Low conductivity indicates excess bleed, which wastes water/chemicals and contributes to corrosion. If conductivity is significantly above set point (high), check for blocked bleed valve. High conductivity indicates inadequate bleed, which can cause scale deposits, fouling and eventually system shutdown.

2. Check chemical feed equipment daily. Check chemical pumps for prime and operation. Re-prime or repair as needed. Inspect chemical feed system for leaks. Check inventory in chemical feed/storage containers. Verify chemical levels in container are dropping as expected.

3. Regularly inspect the spray nozzles and condenser tubes. Poor water flow over the condenser tubes reduces cooling efficiency and will cause deposits to form regardless of water treatment measures. Bugs, cottonwood seeds, scale or any other foreign material can restrict strainers and spray nozzles. The frequency spray nozzles should be checked depends on the condition of the system and the surrounding environment. Clean systems should be checked no less than quarterly. Moderately scaled or fouled systems should be
checked weekly, but monthly may be adequate. Regular inspections can also indicate whether the water treatment program is performing as intended.

4. Check heat exchange equipment for signs of fouling such as a high head pressure and/or approach temperature. Any deterioration of heat transfer is a serious concern that should be addressed immediately.

Conclusion
The water treatment program for an evaporative condenser system is integral to the operation of an energy, water and resource efficient facility. Obtaining good results from the water treatment program has huge economic payoffs and helps meet environmental objectives on many levels. Effective water treatment can help facilities ensure reliable operation of critical refrigeration systems, reduce energy and water use, and minimize greenhouse gas emissions. Effective water treatment is a cost-effective green technology that can offer substantial return on investment.