ASHRAE Journal's

Practical Guide

Operation and Maintenance Of Evaporative Coolers

By Will K. Brown, P.E.
Member ASHRAE

Evaporative cooling (air conditioning) was used long before the advent of mechanical refrigeration and its application to comfort cooling. Equipment and systems are available for residential, commercial, agricultural, and industrial markets. Within each market, a wide range of configurations and applications are available. Direct evaporative cooling most often is thought of and used to provide temperature reduction. However, it is also a humidifier. Consequently, it is applied to provide year-round cooling and/or humidification.

In recent years, the development of highly effective indirect evaporative coolers has broadened their application to include ventilation air precooling. Indirect evaporative cooling in combination with direct evaporative cooling (two-stage coolers) enhances overall system performance. Evaporative coolers have been integrated into systems that use mechanical cooling to reduce or displace part of the annual refrigeration load.

Evaporative cooling is environmentally friendly. Electricity usage is limited to that associated with pumping water and the fan energy to overcome the wetted-media resistance. Whenever direct and/or indirect evaporative cooling displaces or reduces electrically generated mechanical cooling, less power plant emissions are discharged to the atmosphere. Based on U.S. national averages, recognizing the mix of generating technologies, each kWh reduction in electricity usage reduces emissions by 1.48 lbs (672 g) of CO_2, 0.016 lbs (7.3 g) of SO_2, and 0.007 lbs (3.2 g) of NO_x. Reducing CO_2 reduces global warming. The other reductions reduce corrosion and smog.[1]

Direct evaporative cooling improves indoor air quality (IAQ) by its cleansing effect as in industrial scrubbers. It reduces the concentration of dust, smoke, pollen (not removed by upstream particulate filters), soluble volatile organic compounds, and other pollutant gases as the air passes through the cooler's wetted-media.[1]

Evaporative cooling technology has many thermodynamic and environmental advantages. Do concerns about maintenance, air quality, and water quality limit more widespread use? These issues are the subject of this article.

Design

As with any system, design of a component, a complete package, or an entire system affects maintenance and other issues. The following are design recommendations for evaporative coolers:

- Wetted components should be constructed of corrosion-resistant materials such as 304 stainless steel and suitable thermoplastic.
- Avoid coupling dissimilar metals subject to galvanic corrosion. Where coupling is necessary, isolate the dissimilar metals with a suitable dielectric.
- Where media water distribution headers are used, provide means for online flushing.
- Provide simple float-type flow meters with integral valve for measuring and controlling water supplied to the distribution header and bleed-off.
- Provide sloped positive draining pans and sumps.
- The component, package, or system should be designed for maintainability. Components that require periodic inspection and/or service should be easily accessible.

Finally, there is overall quality. While quality may be subjective, the overall construction and component parts must be suitable for the operating environment, intended application, and expected life span without undue risks of nuisance failures. Increasing quality reduces future maintenance and repairs.

Air Quality

Concern about air quality perhaps has been overstated due to misinformation. As air passes through a direct evaporative cooler's wetted-media, it evaporates

About the Author

Will K. Brown, P.E., is a retired consulting engineer and a member of ASHRAE's Technical Committee on Evaporative Cooling as well as SPC-133 and SPC-143 on methods of testing and rating evaporative coolers. Will has received the Crosby Field award and the best symposium paper award in 1986.

water. The resulting vapor is free of pollutants, minerals, and bacteria.

A properly designed system, operating within the recommended face velocities, will not have water carryover. The maximum face velocity for a rigid-type media is about 700 fpm (3.56 m/s). However, systems are generally designed for around 500 fpm (2.54 m/s). The primary airstream passing through an indirect evaporative cooler does not come in contact with water.

Besides acting as a scrubber for removing water-soluble gases, the wetted media has some particulate removal capability. That capability depends on media type and thickness. For example, a 12 in. (305 mm) rigid media has an ASHRAE Standard 52 dust spot efficiency of about 16%, which is equivalent to a fiber furnace filter. This level of filtration would not be adequate for many applications. Therefore, upstream filtration should be equal to that which would be provided in a system without evaporative cooling. Depending on filter efficiency, upstream filtration has the further benefit of reducing pollen, microorganisms, and potential nutrients before the air enters the wetted media. Removing these contaminants significantly mitigates potential air/water quality concerns. Reducing particulate pollutants also decreases potential water distribution system fouling problems.

Concern often is expressed about potential microbial growth in downstream duct systems. The justification for this concern is no greater than, and is often less than, a system with refrigerated cooling. For example, air leaving a wetted-media with 90% saturation effectiveness will range from 88% RH to 96% RH corresponding to wet-bulb depressions of 26°F (14.4°C) and 6°F (3.3°C) respectively. If the saturation effectiveness is only 50%, leaving air will be down to about 54% RH to 86% RH for the same wet-bulb temperature depressions. See Chapter 19 in the *1996 ASHRAE Handbook—Systems and Equipment* for information on how to calculate saturation effectiveness. By contrast, when a refrigerated coil operates under dehumidifying conditions, the leaving air can be saturated to ±99% RH.

Considering these factors, the air quality leaving a direct evaporative cooler and entering a distribution duct system is no worse than that leaving a refrigerated cooling coil and often is better.

Water Quality

In the United States, secondary drinking water standards provide guidelines for taste, odor, color, and certain non-aesthetic effects of drinking water. The Environmental Protection Agency (EPA) recommends these standards as reasonable goals. Although federal law does not require water systems to meet these goals, they can be enforced at the state or local level. Two criteria of interest for evaporative coolers are 500 mg/L of TDS and a pH in the range of 6.5 to 8.5.

Evaporative cooler makeup water should be supplied from a drinking water quality source. Untreated surface water sources should be avoided due to the potential for a high concentration of nutrients and other pollutants. Some industrial facilities have their own treatment plant for producing high purity water. Use of this water, with limitation, may be acceptable as discussed later.

Waterborne diseases are rare in the United States because most water utilities disinfect the water and monitor and test for microorganisms. Microbial growth is always a concern where water is exposed to air. Algae, bacteria, and fungi need nutrients to proliferate. By using drinking quality water for makeup, the outside air to be conditioned will be the most likely source of nutrients. Depending on efficiency, upstream filtration can significantly reduce the concentration of these potential nutrients. A water bleed, required for scale control, also will keep nutrients that might penetrate upstream filtration from concentrating in the recirculating water.

Besides moisture and nutrients, algae need light to grow. Evaporative coolers that have the wetted media attached or in close proximity to inlet louvers can be particularly susceptible to algae. Providing a barrier of shade cloth or awnings will inhibit algae growth. Most commercial and industrial systems are designed so the evaporative component is contained within a housing that is not exposed to light. The same is true for semi-custom designed packages. This is particularly true for systems that provide conditioned air for environments with human occupancy. In these situations, algae growth would not be expected. In situations or applications where algae growth is a potential problem, the coolers should be shut off for several hours a day to allow the media to dry. Algae cannot live where it is dry. Such cycling should be limited to once per 24 hours.

Legionnaires' disease is not a problem inherent to evaporative cooling. The disease is contracted by inhaling an aerosol (1 to 5 micro-meter in diameter) laden with sufficient *Legionella* pneumophila bacteria into the lower respiratory system. Wetted-media type evaporative coolers do not provide suitable growth conditions for the bacteria and generally do not release an aerosol. A good maintenance program reduces microbial problems and the concern for disease transmittal.[2]

Adequate bleed-off is essential for good maintenance and to minimize potential problems. Since pure water is evaporated, the concentration of minerals, nutrients, and other pollutants in the recirculating water continues to increase. Bleeding off a portion of the recirculating water and replacing it with fresh water limits the maximum concentration. Bleed-off is the primary and preferred means for scale control. Makeup water replaces water that is bled off and evaporated.

The term "cycles of concentration" is the ratio of recirculated to makeup water concentration. The amount of bleed and makeup as functions of the evaporation rate and the cycles of concentration and are given by:

$$B = E/(C-1)$$

and

$$M = B + E$$

where,

B = Bleed-off, gpm (L/s)

E = Evaporation rate, $= \Delta T \times AF/491{,}000$ (2,000,000), gpm (L/s)

ΔT = Entering dry-bulb temperature – Leaving dry-bulb temperature, °F (°C)

AF = Airflow, cfm (L/s)

C = Cycles of concentration, dimensionless

M = Makeup rate, gpm (L/s)

Depending on the hardness of makeup water, the cycles of concentration can range from about 6 down to about 2, with 3 to 4 being typical. When C = 3 to 4, the makeup rate will be 1.5 to 1.33 times the evaporation rate. The water utility can provide water quality data from which the cycles of concentration can be determined.

The recirculated water should be limited to a maximum silica content of 150 ppm (with 100 ppm preferred). The $CaCO_3$/alkalinity ratio should be maintained to achieve a Puckorius Scaling Index (PSI) of 6.0 to 6.25.[3] *Figure 1* is a curve for stable water, which is neither scale-forming nor corrosive. It has a PSI of 6 based on water at 70°F (21.1°C) and conductivity in the range of 300 to 1,000 micromhos.

The curve in *Figure 1* can be used to determine the desired cycles of concentration. First, assume cycles of concentration or a scale-up factor higher than the anticipated operating cycles, say between 5 and 8. Raw water $CaCO_3$ is multiplied by the scale-up factor. Raw water alkalinity is estimated to increase by 0.67 × the scale-up factor. The 0.67 multiplier is applied because the alkalinity is not stable and does not scale up at the same rate as other water constituents. A point representing these values is plotted on the chart, and a straight line is drawn through that point and the origin (0,0). The line intersects the stable water curve at the desired recirculated water concentration of $CaCO_3$ to be stable or non-scaling. The desired cycles of concentration are then given by:

$$C = \frac{\text{Recirculated water CaCO}_{3\,\text{(from the chart)}}}{\text{Raw water CaCO}_3}$$

For example, assume a raw water source where $CaCO_3$ is 75 ppm, alkalinity (as $CaCO_3$) is 93 ppm, and the scale-up factor is 6. The scale-up factors become 450 ppm (6 × 75) for $CaCO_3$ and 374 ppm (6 × 0.67 × 93) for alkalinity. Following the procedure outlined earlier and as illustrated in *Figure 1*, the $CaCO_3$ concentration read from the x-axis is 300 ppm. The desired cycles of concentration are:

$$C = 300/75 = 4$$

The design bleed-off and makeup rate should be calculated from the design evaporative cooler load (entering minus leaving air temperatures). The load is converted to the amount of water evaporated based on the enthalpy to vaporize water at the design wet-bulb temperature. The amount of evaporation can be determined from the simplified equation:

$$E = \Delta T \times AF/491{,}000\ (2{,}000{,}000),\ \text{gpm (L/s)}$$

as given above. Some margin should be provided in sizing the makeup in case operating experience indicates that decreasing the cycles of concentration is desirable. Decreasing cycles of concentration require increasing bleed-off and resulting makeup. Unless a particular design dictates otherwise, design criteria based on the ASHRAE 1% DB/MWB are recommended.

A fixed rate of bleed based on design conditions will bleed more water than necessary at reduced load. Using a conductivity controller and solenoid valve to regulate bleed will reduce water consumption and maintain the recirculated water concentration at the desired operational level. A conductivity controller has the further advantage of changing the setpoint to obtain a different bleed rate should operating experience dictate. In general, conductivity controllers are practical and economically justified only in larger systems and/or systems with long annual hours of operation. However, some manufacturers offer proprietary devices (based on actual recirculating water pump operation and or time) to regulate bleed and thereby conserve water on smaller packaged units. Whether the bleed rate is fixed or controlled, means should be provided to adjust and measure bleed flow for the design rate.

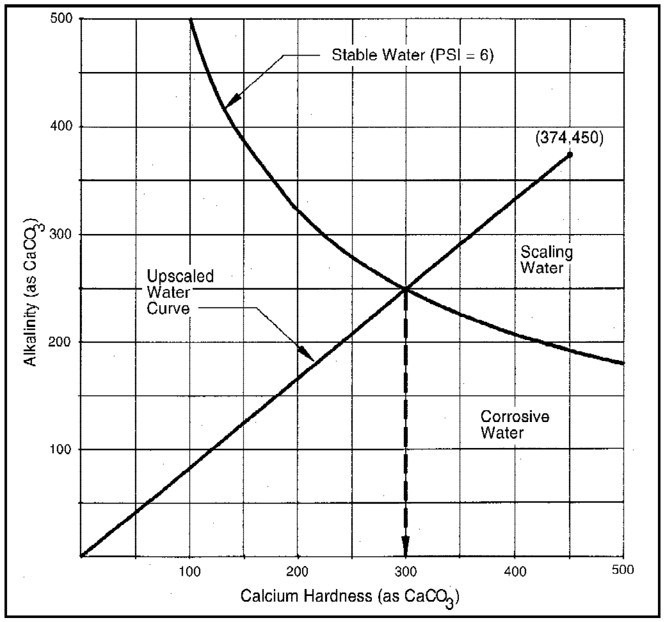

Figure 1: Water quality chart.

With the appropriate bleed rate, the system should operate in a slightly scale-dissolving range with no visible signs of scale buildup. Operating in this range also should reduce potential microbial problems.

The use of RO water exclusively for makeup is not recommended. This water is low in minerals, making it ideal from a scale standpoint. However, its conductivity is also low. Low conductivity water is aggressive and can be deleterious to the media and other wetted components such as brass valves and galvanized parts. A better solution may be to use RO water blended with raw water to produce acceptable quality makeup water. RO reject water is not appropriate for makeup because its mineral concentration is greater than that of the raw water. The use of RO or blended water should be discussed and approved by both the equipment and media manufacturers before implementation.

The manufacturer's recommended recirculation water flow rate is intended to provide excess flow over that evaporated. In other words, some water should always return to the sump. This is important because the excess flow provides a means to flush the media. This flushing controls scale and cleans the media. Without excess flow, there would be no way to remove the minerals that the evaporated water leaves behind. Scaling would definitely occur. For a rigid media, a minimum of 1 gpm/ft^2 (0.68 L/s per m^2) of horizontal media area (width × depth) should drain off the bottom of the pad. This rate plus the design evaporation rate needs to be distributed to the top of the media.

The presence of an odor (often described as fishy) indicates a scaling and/or microbial growth problem. Periodic inspection of the media helps avoid problems. Since evaporation is greatest on the inlet side of the wetted media, the onset of scaling will be most prevalent and easily observed on the inlet side. If scaling is detected, first increase the recirculation rate. Then, increase the bleed if necessary.

Chemical Treatment

Chemical treatment should be an option of last resort. Good housekeeping and adequate bleed-off will, in the majority of applications, alleviate the need for chemical treatment. If such practice prove insufficient, chemical treatment may be warranted.

For biological fouling, a non-oxidizing biocide (such as quarternary amines) is recommended. These compounds control a broad range of organisms, are effective over a wide pH range, and are easier to administer than oxidizing agents.

For scale remediation, crystal modifiers such as sulfonated polystyrenes and polymaleic acid should be considered. These products do not prevent scaling but change the crystal form to a non-adherent sludge that is easy to flush from the media surface. Proprietary chemicals that keep minerals in solution also are available. These chemicals allow systems to operate with higher cycles of concentration thereby reducing bleed-off without scaling. Using these chemicals requires continuous monitoring and control of injected chemical into the recirculated water.

Biocides must be EPA-approved for the intended application and administered and maintained by a competent water treatment service technician. The chemical treatment program should be reviewed with the equipment and media manufacturers to ensure compatibility.

Humidification

Adiabatic saturation (evaporative cooling) often is not considered or recognized as a viable humidification technology. Yet, there are quality and economic advantages when compared with other options such as steam injection, infrared, air injection (atomizing), or ultrasonic. From a control standpoint, humidifying with a wetted-media is saturation limited because the media has less than 100% saturation effectiveness. Consequently, high-limit controls are not needed to preclude super saturation in the distribution ductwork. Since only pure water is evaporated, means to provide chemical and/or mineral-free moisture are not required as they are for other options. Maintenance and equipment costs are moderate compared to other.[4]

In a 100% outside air-makeup system, the thermal energy cost to humidify is essentially equal for all technologies. However, when humidification by wetted media is incorporated in an economizer system using a mixture of outside and return air, the energy content of the return air provides a significant portion and sometimes all of the energy to humidify.[5]

Maintenance

Evaporative cooling systems require preventive maintenance just as any type of mechanical system does. Systems that operate only during the cooling season will require a program that includes both seasonal requirements and periodic inspection.

Annual startup requirements include, where applicable:

- Replace media based on condition and/or manufacturer recommendations.
- Clean cabinet and touch up.
- Clean, disinfect, and flush sump, recirculation pump, and water-distribution system.
- Flush or replace water filters.
- Lubricate fan and motor bearings.
- Adjust belt tension.
- Adjust bleed-off and recirculation rate.
- Replace particulate filters.

Periodic requirements include, where applicable:

- Inspect media for fouling and adjust recirculation rate and/or bleed-off as necessary.
- Inspect media for any dry spots. Flush distribution header and or filters and adjust flow rate if required.

Annual shutdown requirements include, where applicable:

- Wash down media and flush water system.
- Shut down and drain all water to prevent freezing.

For systems that operate year-round, the same requirements apply as for seasonal systems, except shutdown maintenance is performed on a periodic basis. Minimum recommended frequency is quarterly or as determined from operating experience. Some activities will require a system shutdown. Other operations can be performed on-line. These include blowing down the distribution header and flushing the sump if provisions have been made as recommended in the initial design.

Follow the manufacturer's instructions for all components and equipment to supplement those listed earlier.

Summary

A clean water system is the most important aspect for maintaining an evaporative cooling system. This together with periodic inspection of the media for potential scaling, biological fouling, or dry spots with appropriate remedial action is essential. Good housekeeping practices along with recommended annual/periodic maintenance will produce a well-operating evaporative cooling system without biological, air quality or water quality problems.

References

1. Watt, J.R. and W.K. Brown. 1997. *Evaporative Air Conditioning Handbook*. 3rd Edition, p 458.

2. Puckorius, P.R., P.T. Thomas, and R.L. Augspurger. 1995. "Why evaporative coolers have not caused Legionnaires' disease." *ASHRAE Journal*, 37(1):29–33.

3. Puckorius, P.R. 1983. "Getting a better reading on scaling tendency of cooling water." *Power*, September, 79–81.

4. Lentz, M. 1995. "Choices to make in engineering requirements per ASHRAE 62-1989 and IAQ considerations." *ASHRAE Seminar 42*. Semi-Annual Meeting, Chicago.

5. Brown, W.K. 1989. "Humidification by evaporation for control simplicity and energy savings." *ASHRAE Transactions*, 95(1).