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Evaporation and Water Usage

BASIC THEORY AND PRACTICE

Overview

Water consumed by cooling towers due to evaporation, drift and blowdown can be a concern. Total water usage is simply drift, blowdown and evaporation. When determining water usage, evaporation and blowdown are the main drivers. Tower drift may also contribute, but it is typically in the range of 0.01% or less of the recirculating water rate and negligible in comparison to evaporation and blowdown. It can be considered an alternative form of blowdown; as drift increases, blowdown decreases.

Background

Both open and closed circuit cooling towers use latent heat transfer to drive heat rejection. The cooling tower rejects more heat to the atmosphere by evaporating a portion of the water in contact with the air.

At the same time, the chemistry of the water remaining in the cooling tower is changing. The dissolved and suspended solids, minerals and microorganisms left behind increase the amount of chlorides, calcium and biological contaminants in the water. These can come from make-up water and from the air in contact with the cooling tower water. This constant build up of contaminants requires blowdown to help manage water quality. Blowdown means a portion of the water in the open loop of the cooling tower is drained from the system and replaced with fresh make-up water. The primary purpose of blowdown is to keep circulating water chemistry within tolerance based on materials of construction.

The following factors affect the amount of evaporation and blowdown for an operating cooling tower:

- Ambient air properties (temperature and relative humidity)
- Cycles of concentration allowable
- Tower heat load (temperature range and flow rate)

Note: The cooling tower design makes little to no contribution to the evaporation rate except determining design approach, which equals cold water temperature minus the entering wet bulb temperature. Also note that drift is not considered as it merely subtracts from required blowdown.

Cooling Tower Selection

Since design conditions are usually set before a cooling tower is matched to a duty, it is not a factor in determining how much evaporation will occur. The cooling tower determines the approach of a tower, whereas the process determines the range. Typically, the design range is known and the approach dictated by ambient condition and available space for the tower. Therefore, the specific tower design does not affect the evaporation rate since the needed information is already defined in the performance specification.

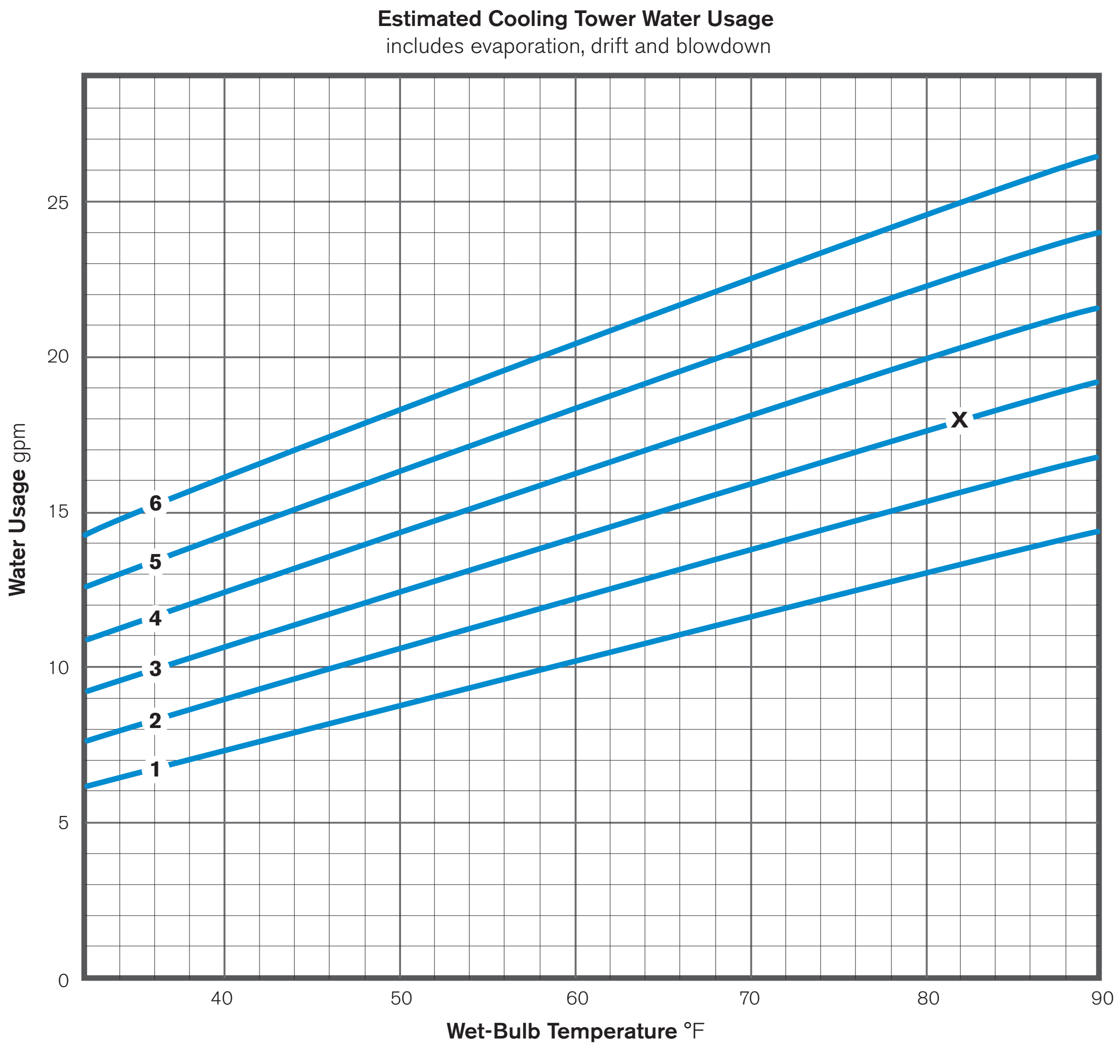
Ambient Air

Like many driving forces in the universe, air has a potential. The cooling tower brings colder air and hotter water into direct contact, so that the air has a potential to absorb moisture and heat from the water. The inlet conditions of the air drive how much potential there is to absorb moisture in the form of evaporation. At lower ambient temperatures, air has less capacity to hold moisture. This, in turn, decreases the amount of evaporation in a tower. Therefore, using the design wet bulb to calculate year round water usage overestimates consumption and is not representative of expected operation. **Figure 1** depicts how evaporation varies with wet bulb temperature. A water usage calculator with usage curves similar to **Figure 1** is available at www.spxcooling.com/green/leed/water-usage-calculator.

Relative humidity also factors into how much water will be evaporated from a tower. The SPX water usage calculator assumes 50% relative humidity. Evaporation will increase inversely with the air relative humidity.

Cycles of Concentration

Cooling tower water needs to be monitored and treated to prevent the continual buildup of the dissolved and suspended contaminants in the water. This is based on the purity of the make-up water, contaminants in the air, and the acceptable levels of certain contaminants advisable for the materials of construction of the tower. As the number of allowable concentrations decreases (less ideal make-up water qualities), the amount of blowdown increases. Resulting total water usage is inversely proportional to the allowable cycles, and therefore increases at low cycles of concentration. **Equation 1** shows the relationship between cycles of concentration and controlling parameters.



Design Conditions

Tower Water Flow	1000 gpm
Hot Water Temperature	95 °F
Cold Water Temperature	85 °F
Wet-Bulb Temperature	82 °F
Drift Rate	0.005%
Concentrations	3

Legend

1 6 °F Range
2 8 °F Range
3 10 °F Range
X Design Point
4 12 °F Range
5 14 °F Range
6 16 °F Range

Figure 1 Cooling tower evaporation estimate based on 1000 gpm with 95°F entering water temperature, 85°F leaving water temperature and 82°F wet-bulb temperature. Multiple range lines at the same flowrate show the change in evaporation rate based on heat load.

$$C = \frac{E + D + B}{D + B} \quad (1)$$

C = Cycles of concentration
E = Evaporation gpm
D = Drift gpm
B = Blowdown gpm

Heat Load (Temperature Difference and Water Flow Rate)

As the cooling tower operates, it will come to equilibrium with the process supplying heat and the entering air carrying away the heat load. As the amount of heat added to the water from the process decreases, so does the amount of evaporation needed to cool the water. Range (the difference between hot water and cold water temperature) and recirculating water flow are combined indicators of the heat load being rejected. Therefore, as the heat load decreases (either through decreased flow and/or decreased range), the evaporation loss to the environment also decreases. Assuming peak heat load for a year round water usage estimate leads to highly conservative estimates for typical HVAC systems or applications where heat load changes throughout the year. **Figure 1** depicts how evaporation is proportional to range.

Drift

Drift eliminators capture liquid water entrained in the discharge air stream. Drift eliminators contribute to safety and cleanliness of areas surrounding the tower. However, controlling drift rate has little to no effect on cooling tower water usage, because it reduces the amount of blowdown marginally.

Drift should not be considered important in the amount of total make-up water needed for the tower. If we assume all water leaving the tower (as drift droplets) to have homogenous chemistry, then drift takes with it the contaminants in the water. This plus the actual directed blowdown is the only way to lower the contaminants concentration in the recirculating water barring filtration and softening. Therefore, drift slightly reduces the amount of blowdown, but does not reduce the amount of total water leaving the system and replaced as make-up.

An elevated (or decreased) drift rate does not change the amount of water needed to leave the tower in order to keep proper water quality and, therefore, does not change the amount of water usage.

By rearranging **Equation 1**, we can calculate two separate cases involving drift. **Table 1** shows the difference, or lack thereof, in total water usage estimated. Note these cases are for demonstration purposes only and 0.2% drift rate is much higher than present drift eliminator technology.

Case 1: 20,000 gpm, 105°F entering water temperature, 85°F leaving water temperature, 78°F entering wet bulb, and 0.2% drift rate.

Case 2: 20,000 gpm, 105°F entering water temperature, 85°F leaving water temperature, 78°F entering wet bulb, and 0.005% drift rate.

Case	Drift Rate	COC	Evaporation gpm	Drift gpm	Blowdown gpm	Total Usage gpm
1	0.200%	3	389	40.0	154.5	**583.5**
2	0.005%	3	389	1.0	193.5	**583.5**

Table 1: Case study demonstrating how drift affects blowdown amount, but does not change the total water usage amount.

Conclusion

- The physical cooling tower selection does not determine water usage.
- Heat load, ambient conditions, and cycles of concentration are the parameters that determine water usage.
- Higher cycles of concentration (as allowed by water chemistry) decrease blowdown and water usage.
- Drift does not affect the amount of overall water usage.

Additional Reading

For additional information on range, approach and additional cooling tower terminology see:

Cooling Tower Perfromance — Approach
www.spxcooling.com/library/detail/cooling-tower-approach

Cooling Tower Perfromance — Range
www.spxcooling.com/library/detail/cooling-tower-range

Cooling Tower Fundamentals
www.spxcooling.com/library/detail/cooling-tower-fundamentals

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