# NOT A DROP TO SPARE: WATER CONSERVATION STRATEGIES IN DATA CENTERS

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## TRENDS AND LIMITS OF AIR COOLED EQUIPMENT

We have seen a trend in the past few years for constructing data centers away from large urban areas. As a matter of fact, some are required to be 50 miles or more outside city centers. The primary reason for a discreet location is to minimize security threats and attacks. For small and medium sized facilities, cooling may be achieved using dry coolers or closed loop air-cooled chillers. The tonnage on these systems however is capped, and considering that a 400 ton air cooled chiller is roughly 40 feet long by 8 feet wide, space requirements become an issue. Large systems with high cooling loads particularly high density IT loads cannot be efficiently cooled without water-cooled chillers and a condenser water loop through an open cooling tower. Evaporation from cooling towers at peak load, particularly in the summer can be substantial. Towers need a reliable source for make up water, which in most cases is fed from the municipality. Some remote locations where data centers are proposed to be built have limited or no availability of municipal water. How should owners and operators plan for their new data center in such a situation? This paper sheds some light on this subject and examines strategies for using systems that require less make up water.

## WATER LOSS THROUGH A COOLING TOWER

Let's investigate how much water is lost during operation of a cooling tower. In HVAC applications, a cooling tower cools a circulating stream of warm condenser water by evaporation to near ambient wet bulb temperature. It is important to note that while the condenser water is circulating between the chiller and the cooling tower, the system is *open* to the ambient and some condenser water will evaporate as it is sprayed or trickled on the internal fill material of the tower

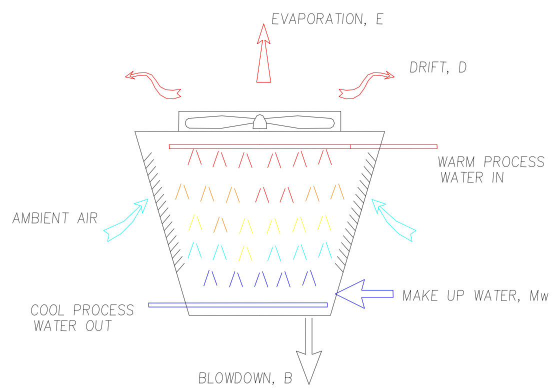


**FIG. 1. Water Balance Through a Cooling Tower**

The rate of evaporation varies with fluctuations in ambient wet bulb and dew point temperature due to seasonality, time of day, and other factors such as wind velocity that contribute to drift. The water loss through the system can be expressed in a water balance equation as follows:

$$M_w = E + B + D$$

Where $M_w$ is the water loss or the Make Up water of the system expressed in *gallons per minute (gpm)*.

E is the Evaporation rate of water through the tower, and at peak ASHRAE design wet bulb conditions, is equal to:

$$E = 0.00085 \times Q \times \Delta T$$

Q = *Tower Flow Rate in gpm*
$\Delta T$ = Cooling tower temperature difference ($T_{water\ in}$ - $T_{water\ out}$)
(A quick rule of thumb is 3 gpm/100 tons-at peak ASHRAE conditions)

B is the Blowdown rate in *gpm* and is expressed as

$$B = Evaporation\ (E) / (CoC - 1)$$

Blowdown rate is a term that refers to the amount of water that needs to be blown off occasionally to reduce the concentration of solids and contaminants from the system. Water evaporates through the tower as pure water leaving behind dissolved solids and contaminants. As more water evaporates, the concentration of solids in the remaining volume of water increases, which will eventually incur buildup of scale in the condenser tubes and heat exchanger plates. In order to reduce this concentration, a portion of the recirculating water is automatically or manually blown off to the drain.

CoC or "Cycles" is the shortcut term for Cycles of Concentration (CoC) and is the ratio of the quality (dissolved solids) of the Blowdown water $BQ_{solids}$ to the Quality of the Make up water $MQ_{solids}$

$$CoC = BQ_{solids} / MQ_{solids}$$

Cycle values are determined by factoring in data from water samples provided by the municipality. Typical cycles range from 2.0 to 3.5 and as high as 7. The higher the cycles, the more savings in make up water.

D is the loss of water due to drift and is typically between 0.1 to 0.2% of the Total Flow Rate (gpm).

It is beyond this article to cover the theory of cooling tower design and water quality chemistry. The reader is encouraged to research the multitude of websites and references that discuss these topics.

*Example*

Let's apply this to a real world problem for three months in the summer. Assume the data center is running at full load from June through August. The facility is located in Maryland and has a total cooling load of 4500 tons. Five 1000 ton induced draft cooling towers serve the condenser water side. Using ASHRAE 1% design of 78.3 F wet bulb at Andrew's Air Force Base, and 85°F - 95°F condenser water temperature range. The water loss at the design summer condition is:

E= 0.00085 x (5000 x 3 gpm) x 10 = 127.5 or 128 gpm

Assuming the water quality is better than average at the location and the resulting CoC is 5.

B = 127.5/(5-1) = 32 gpm

Assuming the cooling tower is placed in a well planned location with drift eliminators

D= 0.1%x5000 tons x3 gpm/ton = 15 gpm

Lost water that needs to be made up:

$M_w$ = 128+32+15= 175 gpm

If this flow rate did not raise your eyebrows, try justifying this to the water company:

Peak make up water per day =

175gpmx60min/hx24h/day= 252,000 gal/day

If this did not raise your eyebrows, try justifying this to the facilities operator paying the water bill (or perhaps the Greenpeace demonstrators picketing in front of your office):

Make up water for 91 days = 252,000 gpd x 91 days = 22,932,000 gallons.

Yes, twenty two million and nine hundred thirty two thousand gallons of make up water needed for the cooling towers in the summer months.

The annual picture is even more troubling. As indicated above, the equations for evaporation use peak wet bulb design temperature; as wet bulb and dew point drop in the winter months, the formulae vary and one may safely conclude that the evaporation rate will be lower.

For an accurate annual usage picture, we resorted to the help of *EVAPCO* engineers. After churning their equations to meet monthly wet bulb temperatures, the annual make up water profile is calculated to be $M_w$ = 61 million gallons a year. Fig. 2 is a graph of the monthly make up water ($M_w$) distribution. The number is a formidable quantity of water to have to make up!

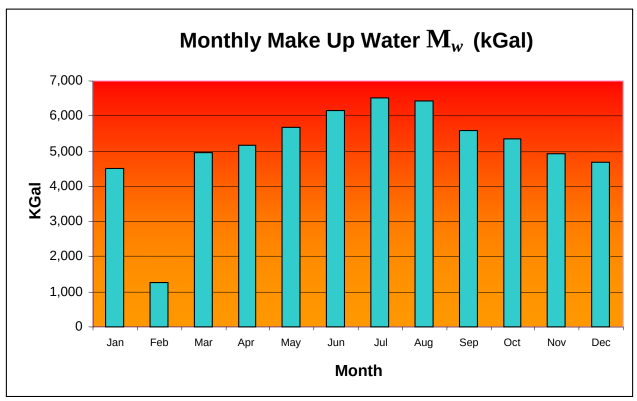


**Fig. 2. Monthly Make Up Water Distribution $M_w$**

## If MUNICIPAL WATER IS AVAILABLE

### Water Conservation Strategies

If municipal water is available at the site, the engineer is professionally and morally responsible to provide the highest water efficient design. If the system can operate between 4 to 7 cycles, with all things being equal, water use reduction is approximately 20-25%. Here are some proven strategies to conserve water consumption:

1. Operate the cooling tower at higher cycles. The maximum cycle at which a tower can operate will depend on the make up water chemistry (pH, alkalinity, dissolved solids etc…). Work with water treatment vendors to optimize the water treatment process and minimize the make up water requirements. Water treatment is one of the largest factors contributing to proper operation of a cooling tower and make up water requirement.

2. Automate the blowdown process. Modern probes, conductivity meters, and controls can measure the dissolved solids and react accordingly to dispense the correct volume of water to keep the concentrations low in the condenser water. Manual blowdown should be avoided as much as possible. Some sources recommend bleed blowdown and continuous make up water. The claim is that the water quality will remain more constant as opposed to allowing the concentrations to build up before being batch bled.

3. Specify cooling towers with drift eliminators to reduce evaporation. Locate towers away from the wind exposed orientation of the building if possible.

4. Investigate the use of closed loop evaporative cooling towers in lieu of induced or forced draft fully open loop towers. While mostly used in industrial processes, nevetheless, there is numerous literature out there on water savings using this type of tower. It is worth noting that while water may be saved, the additional pump energy for the open loop spray water needs to be evaluated.

5. Investigate new water treatment technologies such as electrostatic pulse generators. While still a new technology, this equipment is claimed to help cut down on scale buildup and eventually lead to less water treatment and better water quality. Such equipment works by changing the surface charge of suspended solids in cooling tower water. The shock of the electric pulse breaks up the dissolved solids; the particles settle in the sump, where they can be removed by filtration.

6. Phase out any old cooling towers and budget for a new towers with more efficient louver and internal fill design. As with most equipment, newer models are well thought out with computer models and computer aided design. The result is superior design and tighter tolerance.

### Make Up Water Reduction Strategies

What are some make up water options for reducing the burden on the municipal water supply network? LEED® rating system provides credit to water conservation strategies that the engineer might apply for.

1. Investigate the site for possible water retaining basins. Remote sites often have retaining or percolating reservoirs for storm water drainage. Investigate the possibility of converting percolating basins to retaining ponds and use the water as make up water when required in addition to the municipal supply. A thorough water quality test should be taken at the site to determine if the water is appropriate for use with minimal treatment or not.

2. If reservoirs are not within the vicinity, entrain rain and storm water in catch basins and tanks. Oldcastle Precast (www.oldcastle-precast.com) make gasketed watertight concrete holding tanks that can be installed below grade (under a parking lot during construction). Such systems can hold millions of gallons of water from storm water that is otherwise disposed of in the drain. Once filtered, it is a valuable source for make up water.

3. While sensible cooling is predominant in data centers, yet, dehumidification will be present at some psychrometric room condition. Instead of discharging the condensate into the drain, a collection system could route the condensate into a holding tank for treatment and re-introduction into the make up water system.

## IF MUNICIPAL WATER IS NOT AVAILABLE

### Extreme Remote Locations

If the data center site is chosen in a remote location with no municipal water supply, the designer's first choice would be a closed loop air cooled system. Such systems however, are not practical beyond certain tonnages as the largest air cooled chiller is within 450 tons and the size is roughly 45 feet long by 8 feet wide. If plenty of site space is available, then this might be a viable option.

If cooling loads dictate the need for water cooled chillers, drilling a well may be the only solution for make up water. If the well is determined to be of adequate size to support the facility and natural replenishment from ground water is guaranteed, then an open system with holding tanks may be investigated.

Using surface water such as lakes or rivers for make up water requires careful negotiations with local jurisdictions and Environmental Protection Agency regulation may prevail.

One last strategy will be mentioned: sea water cooling. In some cases particularly international locations, the sea has been used as a heat sink for the condenser water loop. This technology is well practiced and has been adopted in multitudes of commercial projects world wide, however we feel this practice is not very practical for data centers located in the United States. The reader may refer to the web site that discusses this technology

further.
http://www.makai.com/renewable_energy/swac.htm

## Green Design

In cold climate locations, a fluid cooler in a dry cooling mode can be used for free cooling in the winter. A secondary loop switches over from the air cooled chiller to the fluid coolers as needed. In addition to water savings, plant energy consumption is reduced. Vendors of cooling towers will help match the size of a fluid cooler to the facility load during the winter months.

## CONCLUSION

Data Centers operate 24x7 at full or near full capacity and impose a heavy load on make up water to the cooling tower systems. Constructing data centers in remote discreet locations is even more challenging with respect to guaranteeing a steady source of water for proper operation. The good news is that owners, engineers and operators may utilize proven tools and strategies that provide water conservation opportunities. This paper shed some light on the many tools available to the design team.

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