South East Water

Cooling Towers

Cooling towers are the most commonly used means of heat rejection system for building air-conditioning and industrial process cooling applications. Cooling towers work by transferring heat out of pipe networks, which in turn causes water to be evaporated by the process. Although the water within the cooling tower is recirculated numerous times, it must be replenished on a continuous basis subject to heat load and prevailing weather conditions. Hence, cooling towers can consume large volumes of water and account for a major percentage of site water consumption.

Water loss or inefficient operation of cooling towers jeopardises water treatment programs aimed at eliminating legionella and associated operating risks and lead to increased costs for water supply, sewer disposal, water treatment and chemical costs.

South East Water, in conjunction with Melbourne's other retail water companies and the Department of Sustainability and Environment have conducted numerous audits of cooling towers at various customer sites across greater Melbourne to determine the potential savings available through improved Cooling Tower Water Efficiency. While many towers were found to be operating adequately, the trial concluded that on average there is potential for approximately 30 per cent savings to be realised by ensuring cooling towers operate efficiently and are maintained on a regular basis.

Cooling tower efficiency improvements offer the following benefits:

- Better protection against Legionella contamination
- Reduced water costs from reduced tower bleed-off and leaks
- Reduced sewerage and trade waste.

A web based calculator is being developed to help businesses benchmark the performance of their cooling towers and help them operate their systems as efficiently as possible. A 'Water Conservation in Cooling Towers for Operators' training course is also available. Contact South East Water for further information.

In order for your business to measure the water consumption of your cooling towers, South East Water is subsidising the cost of supplying and installing check meters. Please complete the cooling tower metering program application form on South East Water's website.

Important note: *Legionella* risk management

Effective *Legionella* control is a total management system that includes, but is not limited to, management of biocide, water temperatures, environmental conditions and regular maintenance and cleaning. Components and equipment that require maintenance and cleaning include basins, fill pack, drift eliminators and side stream filters.

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Twenty risk factors associated with cooling towers are listed in Australian Standard AS 3666.3:2000 *Air Handling and Water Systems of Buildings – Microbial Control – Performance based maintenance of cooling water systems.*

The conductivity level (or increasing cycles of concentration) is only one factor that can influence *Legionella* control. All twenty factors must be considered in a cooling water management program.

The recommendations about cycles of concentration in this handbook will not compromise effective *Legionella* control and will improve the efficient use of water and chemicals.

The Victorian Department of Human Services publication *A Guide to Developing Risk Management Plans for Cooling Tower Systems, November 2001* deals extensively with the subject of *Legionella* control.

Best practice

Current best practice for water use in cooling towers in Sydney is 800 litres per square metre per annum. This equates to 22 kilolitres per day for a 10,000 square metre office.

'Cycles of concentration' is the relationship between the quantities of blowdown water quality and make-up water quality. With the quality of water supplied by South East Water, cycles of concentration of 8-15 are achievable using a conventional, well-designed, chemical water treatment program. A water treatment program needs to address microbiological, corrosion, scaling and fouling issues. If you are operating at lower cycles, speak to your water treatment service provider.

Major outbreaks of *Legionella* have been associated with ineffective cooling water treatment practices. Scale, fouling deposits and corrosion increase the potential for microbial growth, and their control is very important. They can also affect the efficiency of the cooling system leading to loss of comfort and increased energy bills.

Sydney Water has developed *Water Conservation Best Practice Guidelines for Cooling Towers in Commercial Buildings* to reduce the total demand for water by cooling towers. These guidelines identify ways to reduce water use through better practice, better management, and alternative equipment and water supply. This document can be obtained at:

http://www.sydneywater.com.au/Publications/_download.cfm?DownloadFile=FactSheets/SavingWaterBestPractiveGuidelinesCoolingTowers.pdf.

You should also be aware of Victoria's regulations for cooling towers, available at: http://www.airah.org.au/downloads/2002-03-F01.pdf.

Cooling tower design

In simple terms, an air conditioning system operating in cooling mode extracts heat from the air being supplied to a space and discharges it to the atmosphere.

A cooling coil removes the heat from the air stream, the refrigerant in the coil transfers the heat to a chiller where the heat is transferred to a condenser water system. The condenser water is pumped to the cooling tower then outside air is passed over the water, removing the heat and causing significant evaporation, which is an integral part of the cooling process.

Fans draw air through falling water, causing evaporation. For the most efficient cooling, the air and water must mix as completely as possible. The cooled water then returns to the chiller to complete the cycle.

The efficiency of the tower depends on a number of factors including the flow rates and temperatures of air and water.

Water is usually treated to maintain a clean heat transfer surface, minimise water consumption and meet discharge limits. The spray nozzles in the cooling tower need regular cleaning to ensure effective heat transfer.

A cooling tower consumes water through evaporation, blowdown, drift, splash-out, and overflow.

Evaporation

Evaporation is integral to cooling tower performance, and cannot be reduced without an unacceptable reduction in the performance of the cooling tower.

A general guideline for estimating the rate of evaporation from a cooling tower is 12 litres per minute per 352kW of cooling load.

The rate of evaporation is about 1.2 per cent of the water passing through the tower for every 12°C decrease in water temperature achieved by the tower. The more accustomed figure to accept is 29°C leaving the tower, with 35°C returning to the tower.

The evaporative cooling process is able to reduce the temperature of the condenser water by 5-15°C across the tower; 5.5°C is normal, but 7.5°C is becoming common in more efficient buildings. A cooling tower, however, cannot reduce the temperature of the water below the wet bulb temperature of the outside air.

Blowdown

Blowdown is the term for water that is removed from the recirculating cooling water to reduce buildup of dissolved solids in the tower water. As evaporation occurs, suspended or dissolved solids build up in the remaining water. By removing some of this recirculating water and adding fresh make-up water, the level of mineral scale and other contaminants can be reduced. The quality of the recirculating water directly affects thermal efficiency, proper operation and life of the cooling tower.

Water quality depends on blowdown rate, water treatment, and the quality of make-up water. The greatest opportunity for improving water efficiency is in optimising blowdown in conjunction with proper water treatment. Australian Standard AS/NZS 3666 requires that blowdown is controlled automatically.

Drift and other losses

Drift is a loss of water from the cooling tower in the form of droplets carried out of the tower by an air draft. Reduction of drift through baffles or drift eliminators will conserve water, retain water treatment chemicals in the system, reduce the environmental impact and improve operating efficiency. Drift control is a major part of public health risk reduction strategies.

Other losses of water from cooling towers include:

- Cleaning, as part of remedial or scheduled action, which can use significant quantities of water
- System leakage, which can be a major factor because in an open system leakage is often not discovered unless it is visible.

AS/NZS 3666.1 requires a drift rate of 0.002 per cent.

Splash-out

Splash-out, or windage, is the water that may be accidentally lost by a cooling tower from the splashing of falling water within it or the effect of a strong wind blowing through it. Splash-out can be a major problem with large cross-flow or hyperbolic towers that suffer from strong winds blowing across the basin water surface. Splash-out both wastes water and affects operating efficiency. A remedy is to install a 'wall' in the middle of the cross-flow tower, preventing wind from blowing through it.

Overflow

Overflow occurs when the level of water within a cooling tower basin rises above a predetermined level. Normally this water flows down an overflow pipe into the sewer. Overflow is a common area of water wastage in cooling towers and in some cases can account for up to 40 per cent of daily make-up water. Overflow is often due to inadequate maintenance. It can be difficult to determine if overflow is occurring unless you observe the tower for long periods of time or meter the overflow.

Make-up water

Make-up water is water added to the cooling tower to replace condenser water lost through evaporation, blowdown, drift, splash and overflow. It is regulated using a float valve/level sensor and directly affects water quality in the system. The relationship between blowdown water quality and make-up water quality can be expressed in terms of 'cycles of concentration', where cycles of concentration equals total dissolved solid (TDS) of make up water divided by TDS of blowdown. Efficiency improves when the concentration ratio increases and blowdown decreases.

Significant volumes of water can be conserved by reducing blowdown to the minimum level consistent with good operating practice. Treating the cooling water by physical or chemical means usually reduces the amount of water lost to blowdown.

Studies on cooling towers in Sydney's commercial buildings show that on average evaporation accounts for 88 per cent, blowdown accounts for 5 per cent and drift and splash together accounts for 7 per cent of make-up water.

Water quality management

Principal quality issues are the prevention of scale, corrosion, microbiological growth and fouling. Effective control of these concerns prevents system failure, maintains energy efficiency and minimises system maintenance.

- Scale is formed when minerals in the water collect on surfaces. The formation of scale is affected by pH, temperature and mineral concentration. Scale acts as an insulator, reducing the heat transfer efficiency of equipment. Scale can also obstruct piping, resulting in increased pumping costs. It can be controlled by several methods including adding scale-inhibiting chemicals, controlling pH, softening make-up water and discharging blowdown water to reduce mineral concentrations.
- Corrosion is most commonly caused by the development of microbial biofilm and biofouling. Corrosion inhibiting chemicals can be added to the water to form protective films on the metal or otherwise stop corrosion.
- Bio-fouling is the result of algae, bacteria and fungi growth. It causes blockage of tower water distribution systems, aids the formation of scale and corrosion, inhibits heat transfer and rots wooden tower components. Bio-fouling can be controlled by a number of chemical treatments including oxidising biocides, such as chlorine. When this is poorly managed, problems with *Legionella* can result.

Benefits

- Cost savings from reduced cooling tower cleaning requirements
- Higher concentration cycles lead to reduced treatment chemical cost, although good management is required and cleaning frequency may need to be increased
- Savings from reduced tower blowdowns may include water, sewer and trade waste charges.

Potential water-saving opportunities

Behavioural changes

- Consider moving temperature set points indoors, reducing the amount of heat rejection
- Work closely with your chemical service provider or contracted service provider to reduce blowdown. When buying chemicals for treating cooling tower water, have the provider explain the purpose and action of each chemical. They should provide a written report of each service call, and be sure they explain the meaning of each analysis performed, as well as the test results.
- If appropriate, set up performance-based service contracts with key performance indicators such as level of water use, corrosion rates, microbe levels, etc.
- Make sure you are using the right chemicals for the metals in your system
- Make sure your biocide program is effective and the dosing equipment is appropriate
- Develop a Risk Management Plan. Refer to the Victorian Department of Human Services *A Guide to Developing Risk Management plans for Cooling Tower systems*. This can be downloaded from www.health.vic.gov.au/environment
- All water treatment must be performed by qualified workers and strictly monitored. We recommend you use AIRAH accredited water treatment service companies – further details are available at www.airah.org.au. Work with your water treatment service provider to ensure alternative approaches are safe and appropriate for your requirements
- Consider replacing water-cooled equipment with air-cooled systems. This is appropriate for smaller systems (under a 500kW heat rejection) but may not be suitable for higher capacity or process cooling water
- Minimising the cooling load in a new or existing building will reduce the water used in cooling towers. It will also lead to a more energy-efficient building. Refer to Sustainability Victoria for assistance: www.sustainability.vic.gov.au.

The following ideas save water as well as reduce energy use:

- Use an economy air cycle whenever the outside air conditions are favourable, so that the tower does not need to operate.
- Some buildings are able to use a hybrid type of air-conditioning system which ventilates naturally via open windows whenever the outside air conditions are favourable. Under these conditions the tower does not need to operate. Check the air conditions first, because some areas may have poor air quality and require filtration

- Use heat recovery systems to help minimise the amount of heat rejected through a cooling tower. The saved heat can be used to preheat hot water or even use hot water to re-heat coils
- The Co-efficient of Performance (COP) should be about 10 to 12. Modern chillers have greatly improved this measure – once it was normal at around 2 to 2.5 – and are better than some systems that use shower towers or cross ventilation (The COP relates to chiller efficiency)
- Check whether it is possible to install or use fan motors in towers with variable speed control, saving on energy and extending plant life
- Investigate reducing the lighting load. In many buildings it is possible to effectively reduce the power consumed by the lighting systems by at least 30 per cent without any discernable loss of amenity. Reduced lighting consumes less power and produces less heat, which in turn reduces the air conditioning load
- If planning a new building, use expert hydraulic or design consultants to provide the latest water efficiency initiatives at the design stage
- If planning a new building, investigate different options for cooling. Some systems may use less water but are more energy intensive, so take this into consideration.

Equipment modifications

Fixing water overflows

- Ensure the ball float valve is set correctly. If water flows out of the drain pipe when the pump stops, the most common cause is an incorrectly set ball float valve. Setting the water level correctly can be difficult in towers with a low water volume such as those with a V-shaped basin: too high and you have an overflow problem; too low and you run the risk of emptying the basin on pump start-up. Consider using a break tank to increase the effective volume, or replace the ball float valve with a solenoid valve linked to electronic level detectors. Also check the overflow pipe in the tower is correctly positioned.

  Sometimes an overflow problem can be corrected by a level controller. Check if the ball valve is in a sheltered position within the cooling tower. If the tower is pressurised by the fan, the overflow pipe will require a trap. If it is subjected to water cascade it will require a shield.

- Ensure pipework configuration is not causing overflow. If condenser water pipes run above the height of the tower spray heads, water could flood back into the tower when the pump shuts down. This is easy to observe: just check the tower overflow when the pump stops. Fixing the problem usually requires reconfiguring the pipework. The use of non-return valves is not recommended because over time dirt lodges in the seals and renders them ineffective. Be sure to consult a hydraulics engineer before making changes.

  Walkways in cooling towers often mean the condenser water pipework in the plant room sits higher than the cooling tower basins, creating a need for check valves. If the pipework is out of reach of walkways, maintenance is difficult.

  Incorrect water balance may be an issue where there are two or more interconnected towers. The cause can be as simple as ball float valves set at different heights, in which case the floats need to be adjusted. The cause may, however, be more complex, with faulty pipework design or inconsistent tower basin heights. In these cases an engineering review is required.

- If the area around the cooling tower is wet on a regular basis, water is splashing out. This may be a design issue or it could be due to high winds, and steps should be taken to eliminate the water loss. Anti-splash louvres or splash mats can be effective. Anti-splash louvres have the added advantage of shading sunlight from the tower basin, reducing algae growth. If wind is an issue, suitable windbreaks may also be required.

Leakage from pipes, joints and seals

- Joints may need to be adjusted or sealed if water is leaking from the tower casing or basin. Packed gland pump seals should be replaced with mechanical seals to help prevent any wastage of water. If water is leaking from any pump seal, ensure your maintenance personnel attend to it promptly, even if it is minor; leaks can result in significant water wastage.

Minimising drift losses

- Ensure correct placement of a drift eliminator to help minimise the amount of water and chemicals lost to the atmosphere.

Controlling blowdown

- Most cooling towers are bled off automatically when the conductivity of the water reaches a certain level. Aim to operate the bleed off on a more continual basis, optimising the conductivity of the tower and eliminating wide fluctuations of TDS. Use a conductivity controller to continuously bleed and refill water in the system
- Blowdown is minimised when the concentration ratio increases. Typical concentration ratios have been found to be as low as two to three and generally can be increased up to six or more. Increasing the concentration ratio from two to six will save 40 per cent of the initial make-up water volume. The maximum concentration ratio at which a cooling tower can still properly operate will depend on the feedwater quality, including pH, TDS, alkalinity, conductivity, hardness and micro-organism levels. Most cooling towers in Melbourne can have concentrations of 10 to 12 without detrimental consequences. The extent of use and the sensitivity of a cooling system will also affect how much blowdown can be reduced. Minimum blowdown rates must be determined in conjunction with the optimum water treatment program for cooling water.
- Consider installing check-meters on the make-up water feed line and the blowdown line to better control the blowdown and concentration ratio. Check-meters should, at a minimum, be capable of recording the total flow. Some check-meters also display instantaneous flow. It is important to read and record check-meter data regularly, establish water use and set best practice targets.
- If the condenser water system has a low heat load, the flow of condenser water through the cooling tower can be reduced via a tower by-pass valve. This valve enables the condenser water from the chiller to bypass the cooling tower and return directly to the chiller, thus heating it to a point where maximum cooling can occur across the cooling tower. Minimising the number of times the condenser water flows through the cooling tower minimises water losses from evaporation, splash and drift. Care must be exercised when using a by-pass valve: it can cause rotating sparge cooling towers to stop rotating, and it can compromise spray nozzle patterns if flow through them falls below intended levels. In both cases, the tower can stop working.
- If suspended materials are degrading the quality of cooling tower water, consider installing a side stream filtration system to clean the water. These are rapid sand filters or high efficiency cartridge filters that draw water from the basin, filter out sediment and return the filtered water to the tower, enabling the system to operate more efficiently with less water. This system is particularly effective where the water is cloudy,

airborne contaminants are common or cooling water pipes are small and susceptible to clogging. Removing particles or suspended solids from the recirculating water enables the system to operate more efficiently with less maintenance. Some systems, however, use a lot of water to backwash the filter. In this case, consider capturing bleed-off in a backwash holding tank and use it to backwash the side-stream filters, but firstly evaluate the potential contaminants/dissolved solids in the bleed water. Using a bag or cartridge filter would save even more water because it does not entail a backwash cycle. Before installing a side stream filter, assess all costs, maintenance, and shutdown requirements and the disposal of spent cartridges to landfill

- Some cooling towers may use alternative water sources such as recycled water, stormwater or greywater if the concentration ratio is maintained conservatively low. Similarly, blowdown water may be suitable for reuse elsewhere on the site
- Reduce cooling water overflow on tower shutdown by using a non-return valve on the pump delivery side
- Many facilities use ‘once-through’ water to cool small, heat-generating equipment. Once-through cooling is wasteful because water is used only once before being discharged to sewer. Typical equipment that uses once-through cooling include vacuum pumps, air compressors, condensers, hydraulic equipment, rectifiers, degreasers, X-ray processors, welders and occasionally air conditioners. Options to eliminate once-through cooling include:
- Connecting equipment to a recirculating cooling system. Excess cooling capacity within the plant may be available for use
- Reusing the once-through cooling water for other facility water requirements, e.g. cooling tower make-up, rinsing, washing and landscaping.

Equipment replacement

- Water-cooled chillers may be replaced with air-cooled models. Air-cooled chillers do not use cooling towers, eliminating the condenser water loop. They do not consume water, do not regularly discharge chemicals and water to the sewerage system and carry no risk of Legionnaires disease. They require little water treatment other than ensuring that the chilled water corrosion control chemicals are periodically checked. No harmful chemicals are discharged into the sewer, as there is no need for a bleed system. Air-cooled chillers are also easier and cheaper to maintain, because they do not require an annual clean of the condenser water box. Small (rated less than 500kW) chillers may have lower operating costs. The disadvantages of air- cooled systems are that they:
    - Are comparatively more expensive to purchase
    - Occupy greater floor space
    - Can have a significantly greater electrical demand
    - Are noisier, bigger and heavier
    - Have lower heat transfer efficiency: on very hot days their performance may be compromised and they may have heavy electricity demands.
- Geothermal systems make use of the fairly constant temperature of the ground. Instead of using a cooling tower, cooling water is passed through a series of long loops buried deep in the ground. The unwanted heat is passed to the soil and rocks, where it is dissipated. Since this is a closed loop system, there is little or no water usage. Initially it is more expensive than conventional cooling systems, however because the ground temperature is fairly constant and relatively low, it is possible to achieve very high efficiencies. They are low

noise, have almost no Legionella risk and are relatively low maintenance. However, they require the drilling of bores, which is impractical in built-up areas

- Water source geothermal systems directly or indirectly use underground aquifers. Direct use systems draw water from the ground, pass it through a heat exchanger and return it to its source. Indirect systems use closed pipework loops that pass through the aquifer. Indirect systems are often comparable in cost to a conventional water-cooled system
- Using ice storage and chilled water storage systems overnight can save water and considerably cut operating costs by using electricity at off-peak rates. Capital costs can also be reduced because it is not necessary to install large chillers, etc. to deal specifically with peak loads on only perhaps 10 days of the year. These systems potentially save 15 per cent in electrical energy. Ice systems take up less space than chilled water systems. Tier installation is dependent upon skilled engineering design and manufacture. For this reason they are generally used in large installations. Advice of qualified professionals should be sought at the design stage
- When a building is close to a large water source such as the sea, river or lake, there may be an opportunity to take advantage of the natural heat sink. Several buildings in Sydney, including the Sydney Opera House, make use of the harbour for cooling purposes. Some of the newer buildings in Melbourne's Docklands use sea cooling. There are a number of issues to consider including choice of metals where heat exchanges come into contact with highly corrosive seawater, macro-organisms such as mussels that can foul heat transfer equipment, and limits of chemicals such as chlorine that can be discharged to the water body. Initial costs would normally be higher than a conventional water-cooled system, however the overall benefits may outweigh the initial costs
- Liquid coolers are a similar concept to car radiators, with the cooling tower replaced by a heat exchanger and fan. This is the most basic form of liquid cooler, called a dry cooler. The cooling water is pumped through the heat exchanger and a fan forces air over it. The air picks up the heat and removes it. Because this is a closed loop system, there is little or no water use. The main disadvantage of dry coolers is that they suffer from reduced efficiency at higher ambient temperatures.

  This disadvantage can be overcome in several ways. The simplest is pre-cooling the air by water sprays before it enters the drycooler. Sprays are activated when ambient temperatures become high. A disadvantage of spray coolers is that they must be installed and operated with care to prevent the formation of scale on the surface of the drycooler. Alternatively, pre-cooling pads have the advantage of not creating water droplets on the drycooler surface. Provided the cooling pad systems are properly installed and operated, they present a very low Legionella risk by virtue of their operating temperature.

  Another alternative is a hybrid cooler, similar in principle to the wet/dry cooling towers, except that the condenser water circuit remains closed. A section of the cooling coil surface is wet with water recirculated from a sump at times of high ambient temperature, but at other times the cooler acts as a normal drycooler. By draining the sump at night (when the load on the cooling system is generally low, especially for air-conditioning applications) and running the cooler dry for a few hours, hybrid coolers can be *Legionella*-free and do not need microbial water treatment. The significant advantage of a hybrid system over a conventional cooling tower is lower annual average water consumption

Wet/dry cooling towers use the positive aspects of both systems leading to overall reduced water consumption. Water to be cooled is passed through the dry air-cooled section then through the wet section of the cooling tower. During the cooler periods only the dry cooling tower section is used, reducing water consumption.