Yarra Valley Water | a fresh approach

Best practice guidelines – Cooling towers

Does your building use cooling towers as part of its air conditioning system?

Cooling towers remove heat from a building's air conditioning system by evaporating some of the recirculated water to cool the remainder. While all cooling towers continually reuse water, they can consume a significant percentage of a facility's total water use.

Towers that are in good condition, operated properly and are well maintained allow chillers to operate at peak efficiency.

An audit of cooling towers has estimated that there are 1,800 sites using at total of 35 million litres of water per day for cooling tower operation in Melbourne's CBD.

A trial in Melbourne's central business district shows that annual savings of about 9.5 million litres (or approximately 26%) could be made on water used for cooling towers.

Best practice

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

With the quality of water supplied by Yarra Valley Water, cycles of concentration of 8-15 are achievable using a conventional, well-designed, chemical water treatment program. 'Cycles of concentration' refers to the relationship between the quantities of blowdown water quality and make-up water quality.

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 control of this is very important. These elements can also affect the efficiency of your cooling system leading to loss of comfort and increased energy bills.

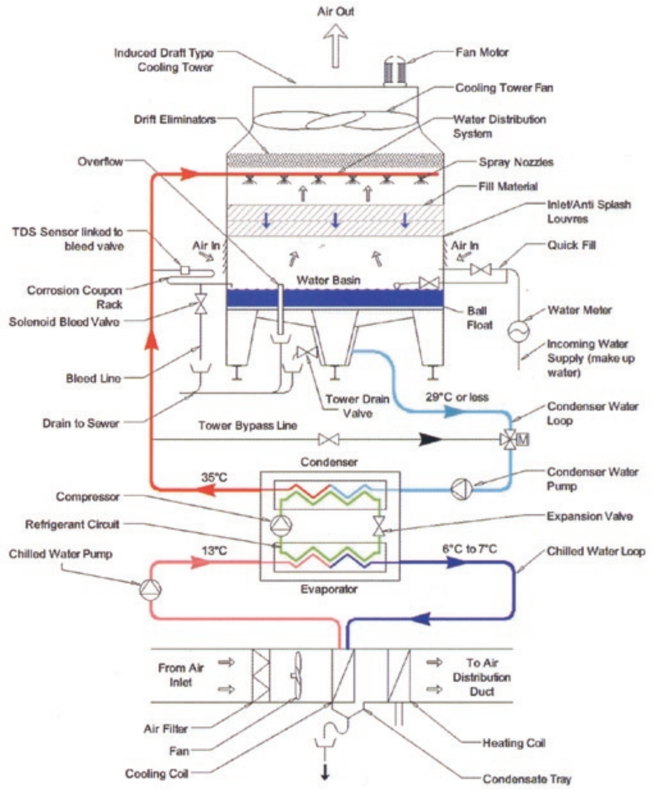
Water loss or inefficient operation of cooling towers means water treatment chemicals are lost, which in turn compromises the effectiveness of the water treatment program and increases the cost of treatment. Optimising your operation and cooling tower maintenance systems can offer significant savings in water consumption.

You should 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.

Schematic of typical cooling water system, courtesy of Sydney Water Corporation

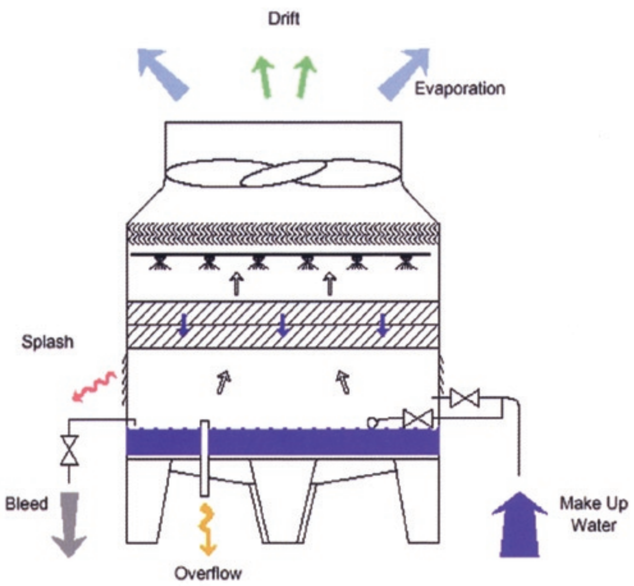


1. A cooling coil removes the heat from the air stream.
2. The refrigerant in the coil transfers the heat to a chiller where it is transferred to a condenser water system.
3. The condenser water is pumped to the cooling tower.
4. Outside air passes over the water, removing the heat and causing significant evaporation - an integral part of the cooling process.
5. Fans draw air through falling water, causing evaporation. For the most efficient cooling, the air and water must mix as completely as possible.
6. The cooled water returns to the chiller to complete the cycle.

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

Schematic of the water balance in a cooling tower, courtesy of Sydney Water Corporation



How cooling towers can lose water

Evaporation

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

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

Blowdown

Blowdown refers to water that is removed from the recirculating cooling water to reduce build-up of dissolved solids in the tower water.

Reducing blowdown to the minimum level consistent with good operating practice can conserve significant volumes of water. Treating the cooling water by physical or chemical means usually reduces the amount of water lost to blowdown.

Water quality is dependent on the blowdown rate, water treatment and the quality of make-up water. 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. It can be reduced by baffles or drift eliminators, which retain water treatment chemicals in the system to improve operating efficiency and reduce environmental impacts.

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

Splash-out

Splash-out, or windage, is water accidentally lost from water splashing or falling within the tower, or the effect of a strong wind blowing through it. Splash-out can be a major problem for 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.

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. It can be difficult to determine the occurrence of overflow unless you observe the tower for long periods of time or meter the overflow.

Overflow is a common area of water wastage in cooling towers, usually due to inadequate maintenance. In some cases it accounts for up to 40 per cent of daily make-up water.

Other losses of water from cooling towers include:

- Cleaning as part of remedial or scheduled action
- System leakage, in which an open system leakage is often not discovered unless visible.

Water quality management

Effective control of scale, corrosion, microbiological growth and fouling, prevents system failure, maintains energy efficiency and minimises system maintenance.

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 to increase your water efficiency. For example, you should understand the purpose and action of each chemical used and the flow-on effect to the amount of water used in your cooling tower.

- If appropriate, establish performance-based service contracts with key performance indicators such as level of water use, corrosion rates, microbe levels etc.
- Ensure you use the right chemicals for the metals in your system
- Ensure your biocide program is effective and 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*. Download from **www.health.vic.gov.au/environment**
- Check that your water treatment service provider has undertaken cooling tower efficiency training with AIRIAH
- Work with your water treatment service provider to ensure alternative approaches are safe and appropriate for your requirements
- Minimise the cooling load in a new or existing building to reduce water used in your cooling towers. It will also lead to a more energy-efficient building. Refer to Sustainability Victoria for assistance: **www.sustainability.vic.gov.au**
- Ensure diligent maintenance of side stream filters and fix leaks including float valves in CT basins

Save water and reduce energy consumption

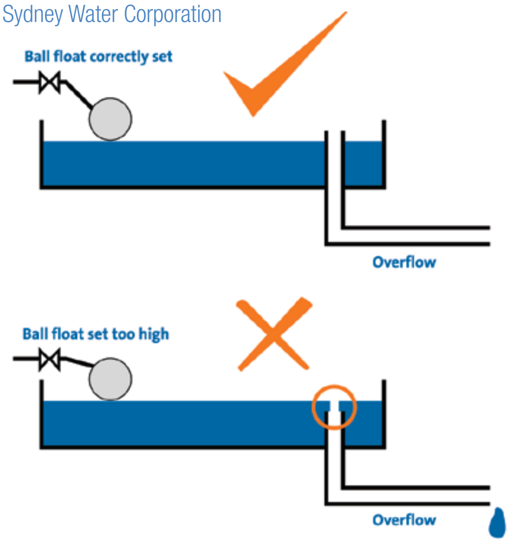
- Whenever outside air conditions are favourable use an economy air cycle so that the tower does not need to operate
- Some buildings can use a hybrid type of air-conditioning system that ventilates naturally via open windows whenever outside air conditions are favourable. Under these conditions the tower does not need to operate. Check air conditions first, as some areas may have poor air quality and require filtration
- Use heat recovery systems to 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 and are better than some systems that use shower towers or cross ventilation (COP relates to chiller efficiency)
- When planning a new building, use expert hydraulic or design consultants to provide the latest water efficiency initiatives at the design stage
- When planning a new building, investigate options for cooling. Consider that some systems may use less water but are more energy intensive.
- Check the possibility of installing or using fan motors in towers with variable speed control, saving on energy and extending plant life
- Investigate reducing lighting. In many buildings you can effectively reduce power consumed by the lighting system 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

Equipment modifications

Fixing water overflows

- Ensure the ball float valve is set correctly and the overflow pipe is correctly positioned. If water flows from the drainpipe 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.

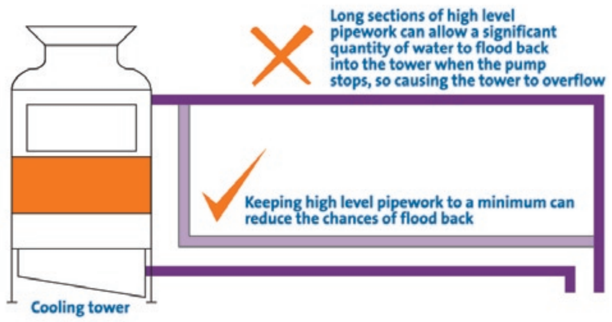
Diagram of correctly and incorrectly set ball float valve, courtesy of Sydney Water Corporation



A level controller can sometimes correct an overflow problem. 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 pipe work 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 pipe work. Non-return valves are not recommended as over time dirt lodges in the seals and renders them ineffective. Consult a hydraulics engineer before making changes.

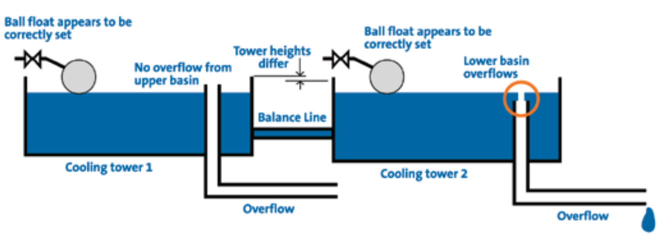
Diagram of correct and incorrect piping configuration, courtesy of Sydney Water Corporation



Walkways in cooling towers often mean the condenser water pipe work in the plant room sits higher than the cooling tower basins, creating a need for check valves. If the pipe-work 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 pipe work design or inconsistent tower basin heights. In these cases an engineering review is required.

Diagram of incorrect water balance in connected cooling towers, courtesy of Sydney Water Corporation



- If the area around the cooling tower is wet on a regular basis, water may be 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, you may also require suitable windbreaks.

Leakage from pipes, joints and seals

- Joints may need to be adjusted or sealed if water is leaking from the tower casing or basin. Replace packed gland pump seals with mechanical seals to help prevent water wastage. 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 the 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 saves even more water, as 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:
  - Connect equipment to a recirculating cooling system. Excess cooling capacity within the plant may be available for use
  - Reuse the once-through cooling water for other facility water requirements, e.g. cooling tower make-up, rinsing, washing and landscaping.

Equipment replacement

- **Air-cooled chillers**

  Water-cooled chillers may be replaced with air-cooled models.

  Benefits to air-cooled chillers include:
  - Do not use cooling towers, eliminating the condenser water loop
  - Do not consume water
  - Do not regularly discharge chemicals and water to the sewerage system, as there is no need for a bleed system
  - Carry no risk of Legionnaires disease.
  - Require little water treatment other than ensuring the chilled water corrosion control chemicals are periodically checked
  - Are easier and cheaper to maintain than water-cooled chillers as they do not require an annual clean of the condenser water box. Small (rated less than 500kW) chillers may have lower operating costs.

  Disadvantages of air-cooled systems include:
  - 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**

  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 dissipates. 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 drilling 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 pipe work loops that pass through the aquifer. Indirect systems are often comparable in cost to a conventional water-cooled system

- **Ice and chilled water storage systems**
  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. Their installation is dependent upon skilled engineering design and manufacture. For this reason they are generally used in large installations. Seek advice from qualified professionals at the design stage
- **Sea cooling**
  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. Issues to consider include the 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 are normally higher than a conventional water-cooled system; however this may be outweighed by overall benefits
- **Dry coolers**
  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 is that dry coolers suffer reduced efficiency at higher ambient temperatures.

  This can be overcome in several ways. The simplest is pre-cooling the air by water sprays before it enters the dry cooler. 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 dry cooler. Alternatively, pre-cooling pads have the advantage of not creating water droplets on the dry cooler 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 dry cooler. 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 over a conventional cooling tower is lower annual average water consumption
- **Wet/dry cooling towers**
  Such towers use the positive aspects of both systems leading to overall reduce 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.

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.

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 20 factors must be considered in a cooling water management program.

The recommendations about cycles of concentration in this guide do not compromise effective Legionella control but 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.

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