EUROVENT MIDDLE EAST GUIDEBOOK
EVAPORATIVE COOLING

EUROVENT
MIDDLE EAST

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EDITORIAL

This Guidebook on evaporative cooling and cooling towers provides a comprehensive overview of this trusted and efficient cooling technology. It is intended for MEP consultants and engineers, as well as for building owners, operators and investors. As an industry association, our aim is to provide such information to a wider audience to increase the understanding of technology and products available in the market.

It is through knowledge that we will achieve energy efficiency and protect our environment, our people and our nations. As President of Eurovent Middle East, I would like to thank our members and the Team for the significant amount of time and effort invested in putting together this excellent reference for evaporative cooling.

Enjoy the reading!

Andrea Cavalet
President

EUROVENT MIDDLE EAST

Eurovent Middle East is the region's HVACR industry association. Its participants constitute leading manufacturers, suppliers, consultancies and service providers of Indoor Climate (HVAC), Process Cooling, Food Cold Chain, and Industrial Ventilation Technologies, as well as sector associations and national industry initiatives active in this field. By thinking 'Beyond HVACR', contributing organisations fulfil the highest requirements in terms of product quality and sustainability.

They are united in their aim to work towards a lower energy demand, improved food safety, and better indoor air quality in the Middle East. Together, they employ thousands of people locally, supporting a more diversified economy throughout countries in the region.

KEY TAKEAWAYS

- **Cooling towers are designed for specific wet bulb temperatures. To establish the correct wet bulb temperature for any given location, refer to ASHRAE or local weather data.**
- **Evaporative cooling is always more energy efficient than dry cooling.**
- **Use evaporative cooling in projects over 500kW.**
- **Consult with manufacturers on the best plant layouts.**
- **Incorrect plant design can lead to recirculation and significantly reduce plant's capacity.**
- **Not maintaining systems regularly results in a loss of money every day.**
- **Water treatment programmes are crucial to maintain performance and avoid harmful bacteria and biocidal accumulation.**
- **Comprehensive maintenance programmes save money.**
- **Quality should never be compromised by questions of costs. Remember, cheap is always more expensive.**
- **Independent third-party certification is essential to avoid discrepancies between published performance data and actual performance.**
- **Factory assembled products with CTI/Eurovent certification do not require any further testing on site.**
- **Eurovent certificates shall be cross checked with an online database to ensure their validity.**

DEFINITIONS

This Guidebook provides a comprehensive glossary on page 27, which contains all specific terminology used throughout the text, defining its meaning to provide a better understanding of the Guidebook contents. All terms within the text which are further explained in the glossary are printed in cursive letters.

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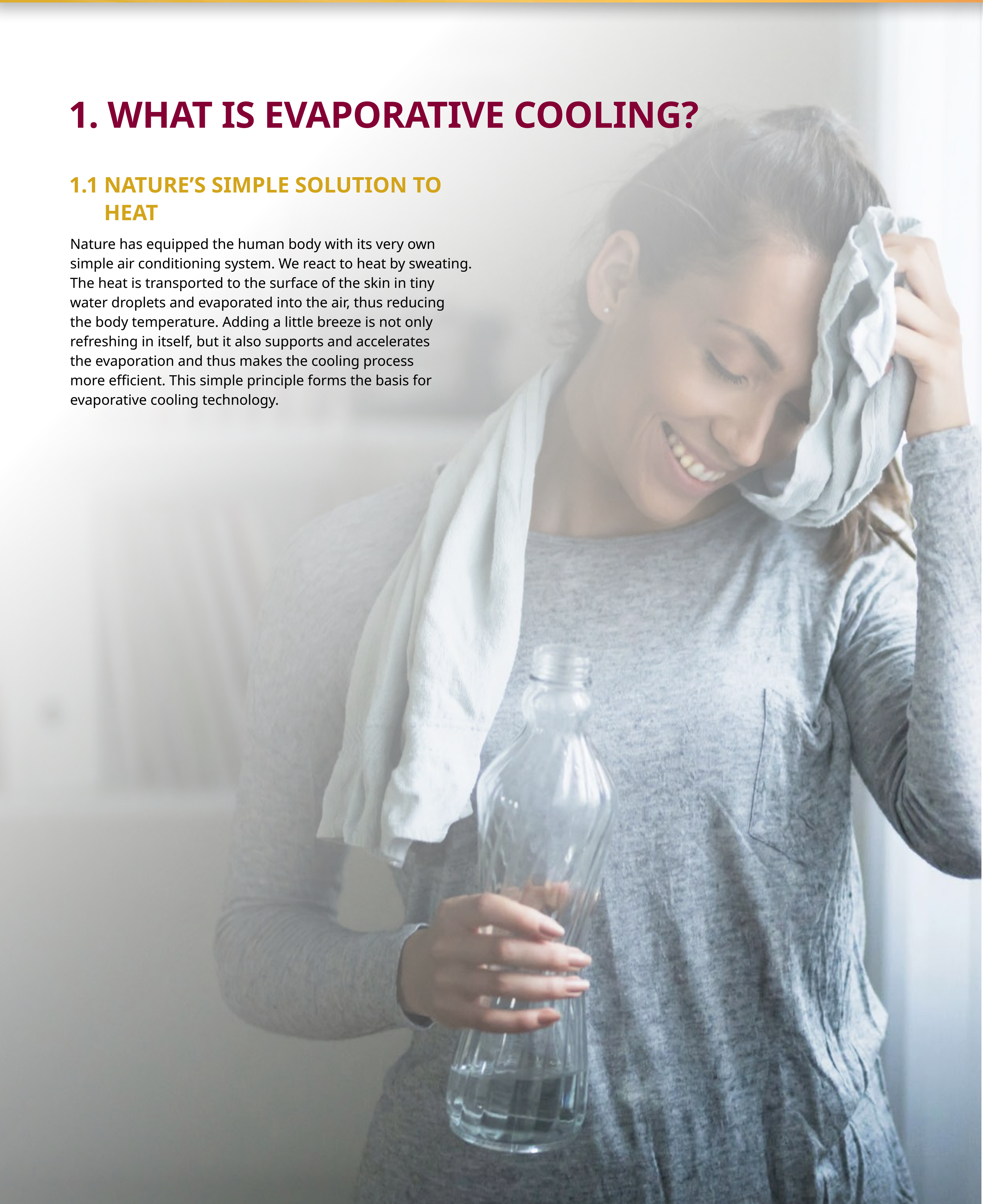


1. WHAT IS EVAPORATIVE COOLING?

1.1 NATURE'S SIMPLE SOLUTION TO HEAT

Nature has equipped the human body with its very own simple air conditioning system. We react to heat by sweating. The heat is transported to the surface of the skin in tiny water droplets and evaporated into the air, thus reducing the body temperature. Adding a little breeze is not only refreshing in itself, but it also supports and accelerates the evaporation and thus makes the cooling process more efficient. This simple principle forms the basis for evaporative cooling technology.

1.2 HISTORY

The principle of cooling towers was already used thousands of years ago. From ancient Egypt to the Arabian Peninsula, wind towers or wind catchers were an effective and popular means of cooling houses or wells. Ambient air was circulated over water in the ground or basement before effectively cooling the inside of buildings. Wind towers are still featured in contemporary architecture.

1.3 HOW IT WORKS

Heat from industrial, refrigeration or air conditioning applications is ejected to the atmosphere. When air is used as a coolant (for example, air blown by a fan across the radiator of a car) one speaks of cooling using sensible heat transfer. If water is used to improve the heat transfer (for example, by the wetting of a surface) one speaks of evaporative cooling, or latent heat transfer. The phase change of the water from liquid to gas, whereby a small amount of water evaporates, is highly efficient at dissipating thermal energy from the water.

The evaporative cooling principle is used in cooling towers, where water is distributed over a heat exchange surface. Simultaneously, air is blown over that surface, causing a small portion of water to evaporate, thus extracting thermal energy (heat) from the water.

1.4 WET BULB / DRY BULB TEMPERATURE

Evaporative cooling uses the difference in wet and dry bulb temperatures. The dry bulb temperature is the ambient air temperature measured with thermometers and what we refer to commonly as the outside temperature. The wet bulb temperature is the temperature read by a thermometer covered in water-soaked cloth over which air is passed (Figure 1). At 100% relative humidity, the wet bulb temperature is equal to the dry bulb temperature. The lower relative humidity levels are, the larger the difference is between the two references. Evaporative cooling makes use of these differences by evaporation of water to lower the temperature of the coolant. The wet bulb temperature is the lowest temperature that can be reached under ambient conditions by the evaporation of water only.

Cooling towers are designed for specific wet bulb temperatures. To establish the correct wet bulb temperature for any given location, refer to ASHRAE or local weather data.

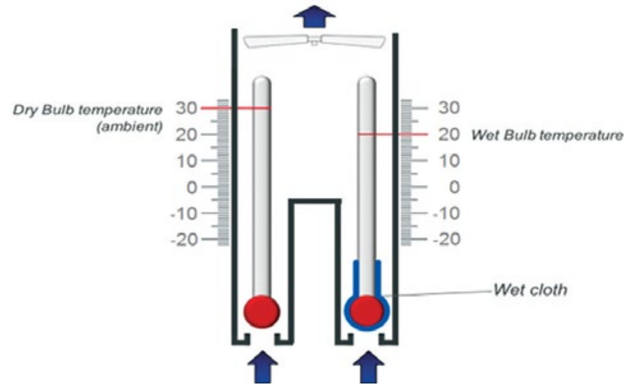


Figure 1: Wet bulb and dry bulb temperatures

1.5 COOLING TECHNOLOGIES

In cooling applications, various technologies are used. Evaporative, hybrid, adiabatic and dry cooling are common terms standing for different techniques of cooling. While dry cooling refers to cooling systems that depend entirely on the ambient air, hybrid and adiabatic cooling systems combine evaporative and dry cooling to adjust to the ambient conditions in the best and most efficient way.

1.5.1 HYBRID COOLING

Hybrid cooling either refers to an alternating cooling with evaporation and dry cooling during a certain part of the year/month/day or utilising a combination of evaporative and dry cooling in a single, energy efficient and water conserving unit.

1.5.2 ADIABATIC COOLING

An Adiabatic Fluid Cooler enhances the utility of a dry air cooler system with the efficiency boost of a wet system during peak conditions, providing lower energy usage and smaller footprint than an air cooled fluid cooler and lower site water usage than an evaporative fluid cooler.

2. ENERGY EFFICIENCY, WATER CONSUMPTION AND THE MIDDLE EAST ENVIRONMENT

Compared to cooling with dry air (sensible heat transfer), evaporative cooling is significantly more energy efficient. With 1kg of water the heat removed is about 2256kJ (heat of evaporation) per °C, while with 1kg of air the heat removed is about 1kJ per °C.

Evaporative cooling is used by almost all district cooling plants in the Middle East, showing the relevance of this technology for the region. However, the use of water can sometimes be an issue in locations with scarce resources. This chapter will provide an overview of the aspects and guidance on when evaporative cooling should be considered and reflects on the conditions in the Middle East.

2.1 ENERGY CONSUMPTION

Because more heat is removed by evaporation than by standard sensible heat transfer, evaporative cooling requires up to four times less airflow for a given heat transfer capacity compared to a conventional air-cooled process. This means that as little as a quarter of the electrical energy used in dry cooling is needed.

Using a cooling tower in HVAC systems not only reduces the energy consumption of the condenser water cooling loop, but also provides better returning water temperatures to the chiller to allow for much lower energy consumption on the chiller itself, the chiller being the most power consuming piece of equipment in the system.

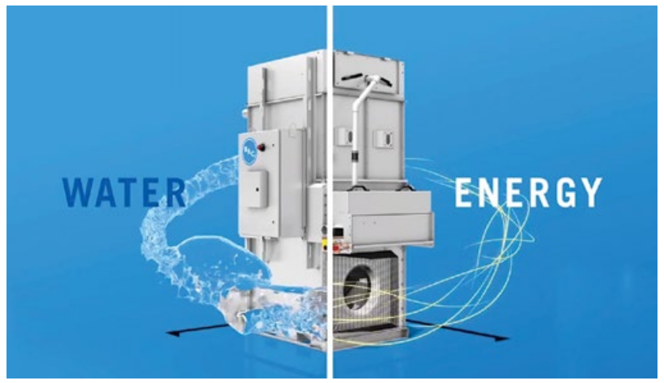
Effective heat transfer combined with lower airflow through the unit makes evaporative cooling equipment a front-runner when it comes to energy savings. Thus, by both application and design, evaporative cooling equipment saves energy and reduces emissions.

> **Evaporative cooling is always more energy efficient than dry cooling.**

2.2 WATER CONSUMPTION

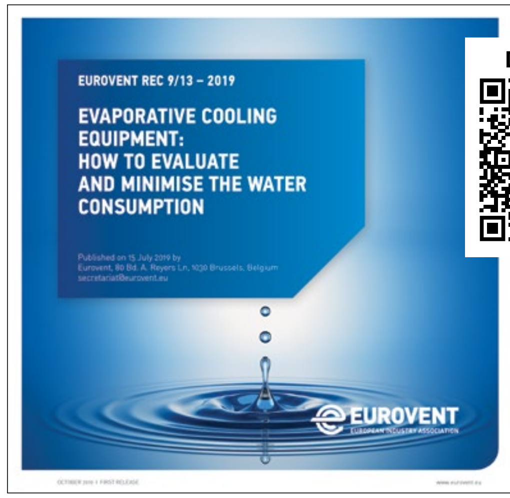
In any cooling system, there is a balance between usage of water and power to achieve the required cooling – this is sometimes referred to as the water-energy nexus. Evaporative cooling systems use the significant efficiency of latent cooling to dissipate large amounts of energy whilst using the lowest amount of energy.

In regions with scarce water resources like in some parts of the Middle East, saving the water usage from evaporation at the cost of higher power consumption may seem preferrable. However, in evaporative cooling systems, the water is recirculated and the water losses through evaporation are rather minimal. On the other hand, consideration must be given to the water that is required for the production of electrical power.



A study published in 2012 by the National Renewable Energy Laboratory found that whilst some renewable power generation technologies such as solar and wind have zero water usage, more traditional methods such as nuclear and fossil fuel (coal, oil, gas) power plants consume 60.000 gallons (227t) of water for each MWh of energy produced. The net overall water savings gained by avoiding evaporative cooling are therefore minimal, while the impact to the carbon footprint as a whole is negative.

For a recent study on water consumption and calculation methods, refer to the Eurovent Recommendation 9/13 - 2019, which is available for free in our Document Library.



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Therefore, as a rule of thumb, the industry on a global scale has tended to aim for water cooled systems whenever the cooling capacity required is over 500kW. In areas where there is a complete lack of water availability, larger heat loads can also be considered for air cooled systems. From a general carbon footprint view however, the approach should be where there is water available to use for cooling, use it.

> **Use evaporative cooling in projects over 500kW.**

2.3 GREY WATER

Many water-cooled HVAC systems now also make use of grey water in the cooling loop, to reduce the burden on municipal water systems. The wastewater from processes or buildings can be treated to be suitable to pass through a cooling tower system, with the components being selected appropriately based on the quality of water supplied from the treatment process.

Check with manufacturers on the best options and design to evaluate your electricity and water saving potential.

2.4 EVAPORATIVE COOLING IN THE MIDDLE EAST

2.4.1 LOCAL CONDITIONS AND CLIMATE DATA

As the cooling towers cool water by evaporation, the wet bulb temperature (WBT) is the critical design parameter. Typically, the WBT in the region is more than 10°C lower than the dry bulb temperature (DBT), enabling lower water outlet temperatures as compared to the air-cooled systems. The amount of evaporation is a function of the difference between DBT and WBT, and the heat load.

The larger the difference between these two temperatures are, the bigger the efficiency gains by evaporative cooling. For example, this means that, even on hot summer days in Riyadh with an ambient dry bulb temperature of 44,8°C, evaporative cooling equipment can easily cool water down to a temperature of 24,1°C. How is that possible? The wet bulb temperature in Riyadh for this period is shown to be 21,1°C. Certified evaporative cooling equipment can cool down to within 2,8°C of the given wet bulb temperature.

To understand the potential and requirements, it is important to look at the full climatic data of a specific location. Such data is provided by local meteorological stations and is also published regularly by ASHRAE.

As cooling systems must be designed to meet the peak cooling load, most air conditioning designs are based on 0,4% annual cumulative frequency of occurrence. For instance, the wet bulb temperature in Dubai, United Arab Emirates will exceed 29,8°C on average 35h (0,4%) in any given year.

2.4.2 LOCAL REGULATIONS

Governments in the Middle East have introduced various measures to reduce the amount of energy needed for cooling. From minimum energy performance standard (MEPS) requirements for air conditioners to energy efficiency labelling schemes. While Kuwait, thanks to the availability of ground water, already mandates evaporative cooling systems for projects over 500t, countries such as the Kingdom of Saudi Arabia have imposed limits to power consumption for building projects, forcing planners to make use of the considerable power savings of cooling towers.

Global climate protection initiatives like the Paris Agreement and Kigali Amendment will result in more demanding regulations on energy efficiency also in the Middle East. Using evaporative cooling technologies therefore also provides insurance to be compliant to upcoming stricter energy regulations.

3. COOLING TOWERS

A large variety of evaporative cooling equipment exists, with different design principles, sizes and construction materials. While natural draft cooling towers depend on the height of the tower, and the associated differential air pressure between the top and the bottom to naturally induce air through the structure, mechanical draft cooling towers work with the support of fans, to create a forced or induced draft.

There are also many options in terms of materials of construction and fan arrangements so the designer can choose the best combination of performance, energy usage and product life for each particular application. Finally, evaporative cooling products are available with a broad range of accessories such as capacity controls or sound attenuation packages.

3.1 OPEN CIRCUIT

Water from the heat source enters an inlet connection and is distributed over the fill pack through a spray distribution arrangement. Simultaneously, ambient air is induced or forced through the tower, causing a small portion of the water to evaporate. This evaporation removes heat from the remaining water. The cooled water falls into the tower sump from where it is returned to the heat source. It is an open circuit as the water to be cooled is in contact with atmospheric air.

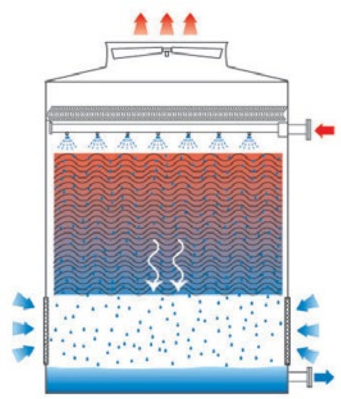

Figure 2: Open circuit cooling tower

3.2 CLOSED CIRCUIT

The fluid to be cooled is circulated inside the tubes of the heat exchange coil. A secondary system distributes water over the tubes of the coil. Simultaneously, air is forced or drawn over the coil causing a portion of the secondary water to evaporate. This evaporation removes heat from the fluid through the coil wall. The secondary water falls to the sump from where it is pumped over the coil again. This is called closed circuit as the fluid to be cooled is in a sealed loop and does not come into contact with atmospheric air.

A combination of coil and *fill* is also frequently used in the market as latest technology to improve system efficiencies.

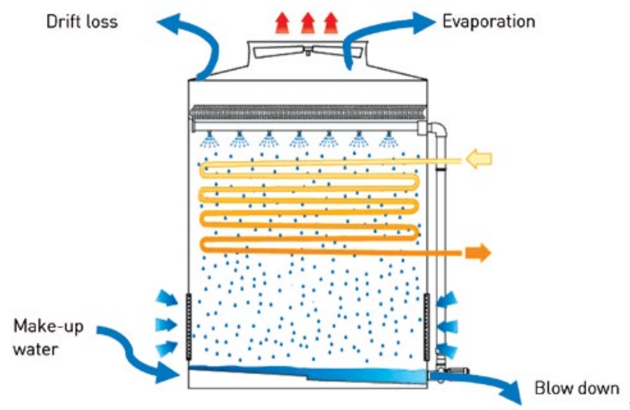

Figure 3: Closed circuit cooling tower

3.3 CROSS FLOW

Warm process water from the heat source enters the water distribution system at the top of the cooling tower where it is distributed over the *fill* or heat transfer media. At the same time air is drawn from the sides of the unit through the *fill*. Because the water is travelling vertically down, and the air is passing horizontally across the *fill*, they cross each other in perpendicular directions, hence the term cross flow.

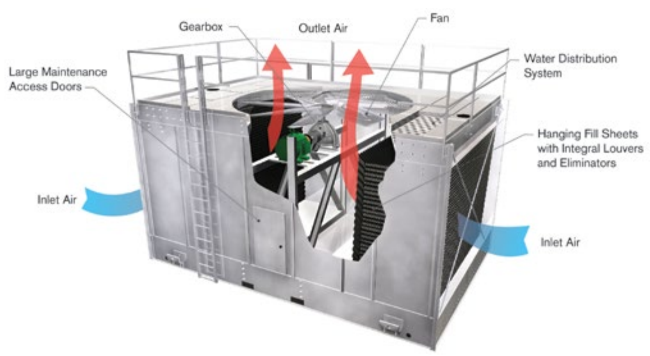

Figure 4: Cross flow cooling tower

3.4 COUNTER FLOW

Warm process water from the heat source enters the spray system at the top of the cooling tower where it is distributed over the *fill* or heat transfer media. At the same time air is drawn or forced from below the *fill*. Because the water is travelling vertically down, and the air is passing vertically up through the *fill*, they are in counter directions to each other, hence the term counter flow.

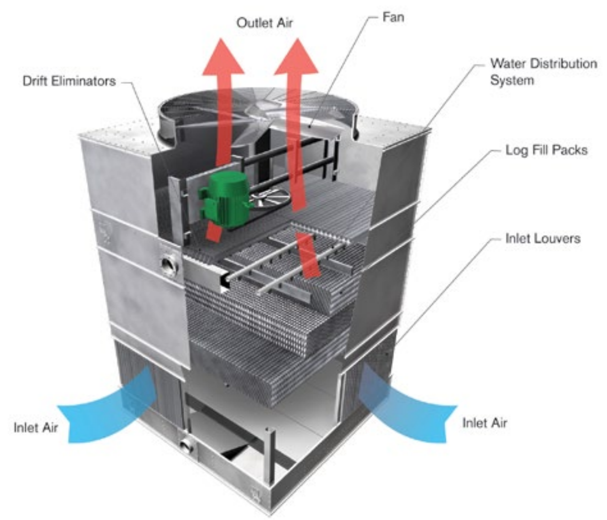

Figure 5: Counter flow cooling tower

While these technologies (cross and counter flow) are most common, equipment with parallel flow or a combination of different flow technologies also exist.

3.5 INDUCED DRAFT

These cooling towers are characterised by the fan located in the discharge air stream, therefore inducing the air through the tower.

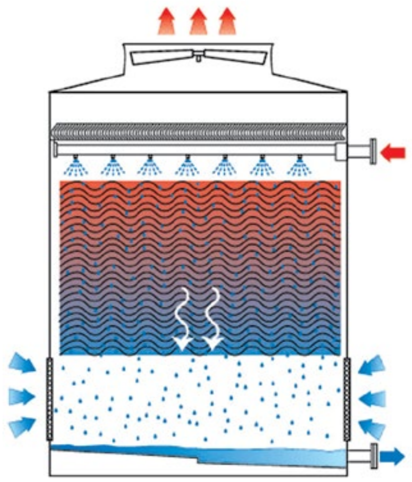

Figure 6: Induced draft, counter flow cooling tower

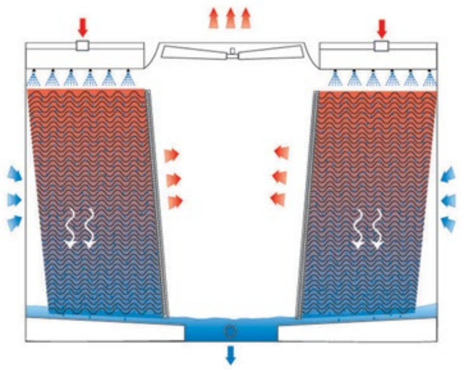

Figure 7: Induced draft, cross flow cooling tower

3.6 FORCED DRAFT

These cooling towers are characterised by the fan located in the entering air stream, therefore forcing the air through the tower.

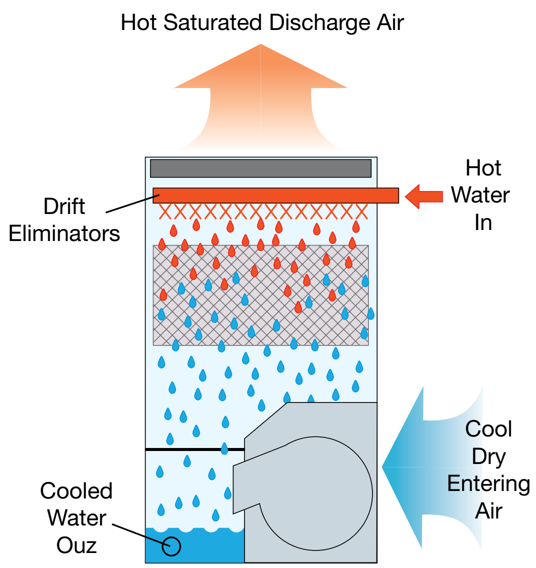

Figure 8: Forced draft cooling tower

3.7 NATURAL DRAFT

Airflow through the tower is produced by the density differential that exists between the heated (less dense) air inside the stack and the relatively cool (more dense) ambient air outside the tower. There is no mechanical equipment to move the air, it occurs by natural air movement.

Figure 9: Natural draft cooling tower

3.8 FACTORY ASSEMBLED AND FIELD ERECTED PRODUCTS

Evaporative cooling equipment is available on the market in a broad range of sizes, from small units, which can be transported fully assembled up to very large units, which require assembly or construction on site.

For factory assembled (packaged) cooling towers, technical and performance data can be published at the time the product is brought to the market. Packaged cooling towers are grouped in product lines consisting of models that are functionally related to one another by a common design and material construction but varying in size and cooling capacities. The models are of consistent type and design in that they employ the same design configuration and the same fan type plus any other design or application consideration the manufacturer may employ. Packaged cooling towers are usually factory produced, however in special instances they can be shipped as a flat package and assembled on site using technically trained personnel.

4. INSTALLATION

4.1 THE IMPORTANCE OF CORRECT LAYOUT DESIGN

The location of evaporative cooling equipment is an important consideration when reviewing system design. Since evaporative cooling equipment requires large quantities of air, adequate spacing around the unit must be provided for it to perform properly. An equally important consideration when laying out the equipment is to place the unit in a way that recirculation is minimised to ensure that the cooling tower will operate at its rated capacity.

The first step in achieving this goal is to consider the many factors that may affect the cooling tower's installation. During the design of the system, special attention needs to be given to space limitations, surrounding structures, existing units, proximity of neighbours, prevailing winds, piping, spacing for safe access, and any possible future expansion plans.

Following these guidelines will provide the best equipment layout which will ensure proper airflow to the unit, minimise recirculation, and allow adequate space for maintenance. Consult with the cooling tower manufacturer to receive guidance on the best plant layout design.

Consult with manufacturers on best plant layouts.

4.2 RECIRCULATION

Recirculation occurs when some of the discharge air leaving the cooling tower flows back into the fresh air inlets of the unit. The heat-laden discharge air leaving the cooling tower is saturated and typically at a higher temperature than the ambient wet bulb temperature. Therefore, any amount of recirculation will increase the wet bulb temperature of the air entering the unit and reduce the available performance of the unit.

For example, if the *entering wet bulb temperature* is increased from 26°C to 27°C, capacity is reduced by approximately 16%, corresponding to an increase in leaving water temperature of approximately 0,8°C. As can be seen from this example, a small increase in the entering air wet bulb temperature has a significant effect on the unit's performance.

In extreme cases where the *entering wet bulb temperature* is increased by 3°C, the available tonnage of the unit is reduced by more than 50%. Thus, it is extremely important that the correct design wet bulb temperature is selected for a specific project. The design wet bulb needs to take into account recirculation in case the cooling tower layout is not ideal. It is recommended to perform a computational fluid dynamics (CFD) analysis during the design phase of a project to eliminate the risk of recirculation. The design wet bulb needs to take into account recirculation and should therefore be specified as *entering wet bulb temperature*, as opposed to ambient wet bulb temperature.

Incorrect plant design can lead to recirculation and significantly reduce plant's capacity.

4.3 INSTALLATION

4.3.1 SINGLE UNIT INSTALLATION

The best place to locate any cooling tower is on a roof by itself. However, when this is not possible, correct layout guidelines must be followed to provide a satisfactory installation. The first item to consider is the position of the unit with respect to other structures. The top of the cooling tower must be equal to or higher than any adjacent walls, buildings or other structures.

When the top of the unit is lower than the surrounding structures, recirculation can be a major problem. If the unit is on the windward side, the discharge air will be forced against the building and then spread in all directions, including downward, toward the air inlets.

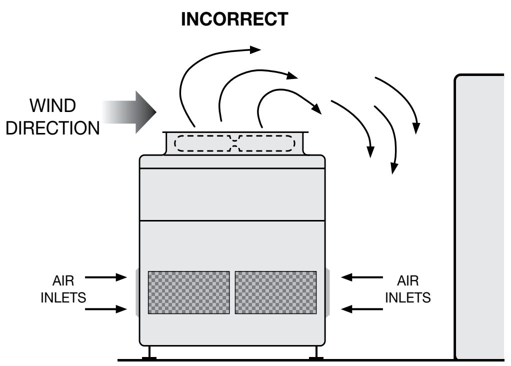

Figure 10: Installation with top of unit lower than top of wall

When the wind comes from the opposite direction, the resulting negative pressure area created by the wind passing over the building will cause the discharge air to be forced back into the inlets. Even if neither of these conditions occurs, the presence of much taller structures can potentially inhibit the dissipation of the hot moist discharge air.

The conditions described above can be corrected by elevating the unit on structural steel, or by adding a discharge fan stack to the cooling tower, so that the top of the fan coil is equal to or higher than the adjacent structures.

When a cooling tower is located near a wall or other structure that blocks fresh air from entering the unit, consideration must be given to the clearance distance between the air inlets of the unit and this blockage. In this type of layout, air will be drawn in through the space between the unit and the wall or other structure as well as down from above. If this dimension is too small, then the velocity of air increases, creating a low-pressure area which will encourage discharge air to be drawn towards the air inlets. Therefore, it is important to provide adequate space in front of each air inlet to ensure proper air flow and prevent air recirculation.

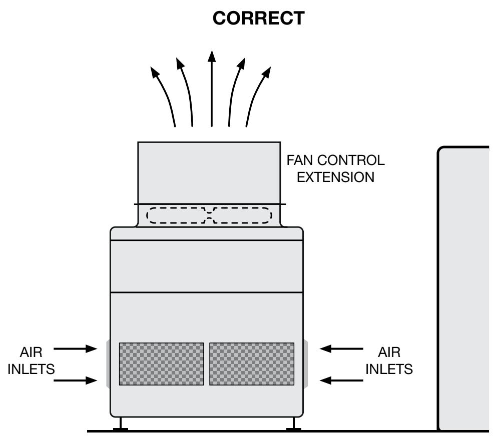

Figure 11: Installation with top of unit at same level of wall

4.3.2 MULTIPLE UNIT INSTALLATION

It is important to provide adequate space in front of each air inlet to ensure proper air flow and prevent air recirculation.

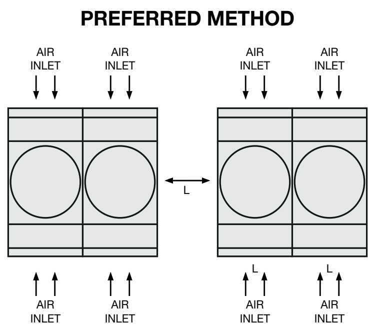

Figure 12: Multiple unit installation

When more cooling towers are installed at the same location, the potential for recirculation becomes a greater concern. For installations with two or more cooling towers, the units may be placed in a variety of locations depending on site conditions and available space.

4.3.3 LARGE INSTALLATION

For large cooling tower installations that have 4 or more units, it is imperative that the unit layout be carefully examined during the design of the system. Very large multiple unit installations can create their own microclimate. Under certain weather and atmospheric conditions, the large quantities of discharge air will cause the wet bulb temperature in the immediate area to be much higher than the local design data. The amount of increase is dependent on the number of units, type of installation, existing equipment and unit surroundings.

Figure 13: Example of a large installation

Another important consideration when dealing with larger multiple unit installations is prevailing winds. Although prevailing wind conditions generally change with the season, the wind direction during the hottest part of the year is of utmost importance. To minimise the potential for recirculation, cooling tower air inlets are to be installed as much as possible out of the prevailing wind direction as shown below.

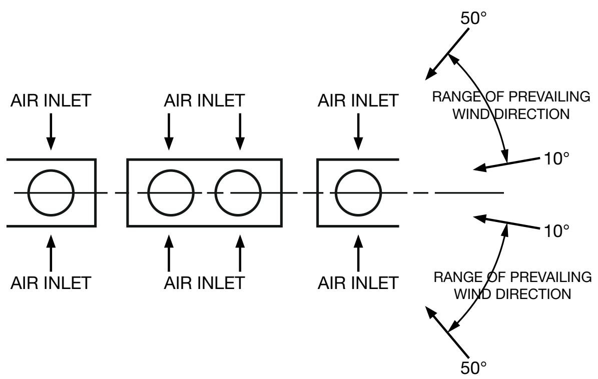

Figure 14: Installation relative to prevailing wind direction

4.4 SPECIAL ENCLOSURES

Occasionally, cooling towers are installed in an enclosure. These installations require special consideration of the unit layout to ensure trouble free operation. Typical installations consist of units installed in solid wall or louvered enclosures or units that are located in a well.

4.4.1 SOLID WALL ENCLOSURES OR WELLS

One typical enclosure is a unit installed in a well (Figure 15). The unit should be oriented so that the air flows uniformly to the air inlets. Additionally, required clearance for all unit accessories must also be taken into account. In the well type of enclosure, all the air must be brought down from above and can be susceptible to recirculation. Field experience has demonstrated that the downward velocity of the supply air into the well must be kept below the manufacturer's recommended velocity to minimise the effects of recirculation.

For the well layouts, minimum distance d (Figure 16) from the wall is the most critical parameter, determined based on the maximum allowable downward air velocity guidelines from the manufacturer. Following equation is generally used:

downward air velocity = unit airflow / usable well area (Figure 17)

Figure 15: Example of well installation

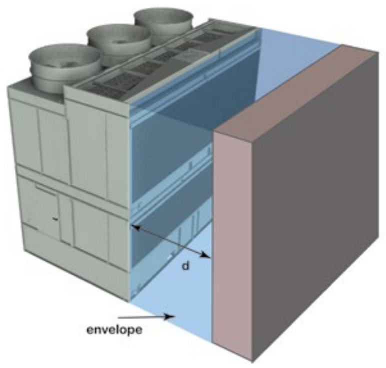

Figure 16: Well layout

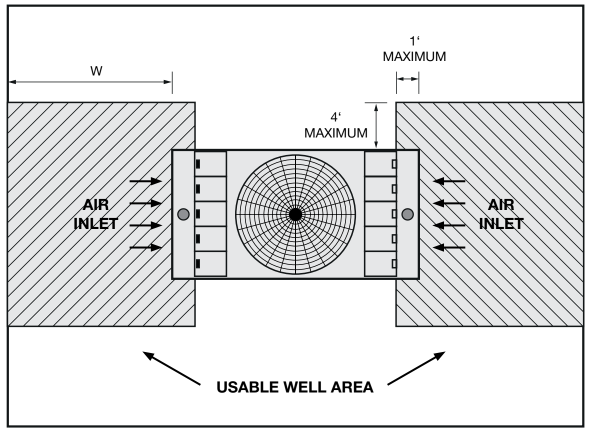

Figure 17: Usable well area

4.4.2 LOUVERED WALL ENCLOSURES

Cooling towers can also be installed in enclosures with louvered or slotted walls. With this type of enclosure, the air flow patterns will be a mixture of the open type and well installations. The inlet air will be drawn from the top and through the *louvers* or slotted openings. Since the air will follow the path of least resistance, the pressure drop through the *louvers* will determine how much air is drawn from both areas. To minimise the potential for recirculation, it is better to draw most of the air through the *louvers*. Therefore, it is important that the louvers are designed for minimum pressure drop.

To achieve this goal, the velocity through the louvers should be maintained at or below 3m/s, the louvers should have a minimum of 50% net free area, and the air inlets should face the louvers.

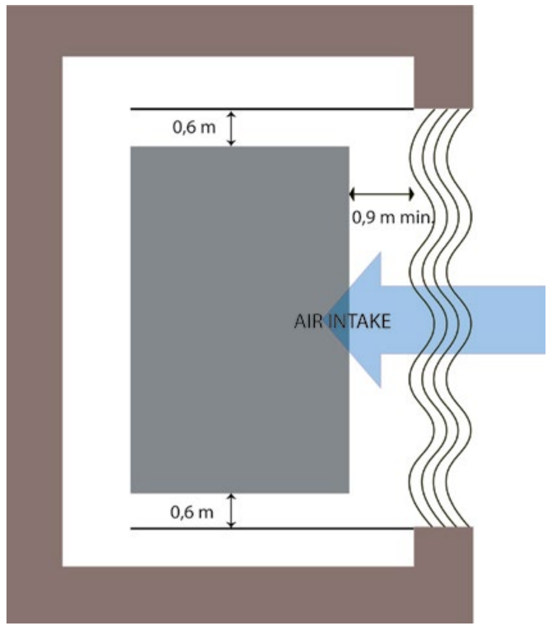

Figure 18: Louvered wall enclosure

4.5 PLUME ABATEMENT

Under certain climatic conditions the water vapour from a cooling tower can be visible in form of a plume. While the plume is totally harmless, containing only condensed water, it may be undesirable especially in densely populated areas. The occurrence of plumes can be calculated, and manufacturers offer different ways to minimise or avoid plumes in cooling towers.

When designing a cooling system with *plume abatement* technology, the design engineer would analyse the weather profile of the installation site to determine how often plume would be visible throughout the year. The design engineer would then determine a suitable plume point, which consists of an ambient dry bulb temperature and humidity, beyond which plume would be visible. This plume point will vary from project to project, depending on the reason for abating the plume, and the individual climate conditions for the site.

Figure 19: Visible plumes

4.6 SOUND AND NOISE LEVELS

Cooling towers emit sound due as a result of the movement of air and the falling of water. In general terms however, due to the efficiency of evaporative cooling and reduced air flow requirements, they tend to be quieter than alternative technologies.

There are 2 scenarios where an engineer may wish to try to limit the sound emitted from the cooling tower; maintaining lower sound close to the cooling tower (near field) for operator health and safety, or at a longer distance away from the cooling tower (far field) so as not to disturb nearby populated areas, such as offices or pedestrian areas.

Typically, an engineer should determine the problem locations, whether near or far, and specify a required sound pressure level to be achieved in those directions, critical time (night/day) and at those distances. Sound pressure tends to be the more useful way to specify this because it is measurable and directional, so it can reflect a real-life scenario, and it can be tested. Sound power can also sometimes be specified; however, it is less useful as it is not measurable or directional.

Various sound test standards are available e.g.:

» CTI ATC-128 – Test Code for Measurement of Sound from Water-Cooling Towers

» ISO 3744 – Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Engineering methods for an essentially free field over a reflecting plane

» DIN 45635 – Measurement of noise emitted by machines; airborne noise emission; enveloping surface method; basic method

The Middle East region is most familiar with the test code by CTI, ATC-128 (2019). This test code provides standard test procedures for measuring the near-field air borne sound from water-cooling towers with reproducible and consistent results. The results obtained could be used to demonstrate compliance with the guarantees offered by the manufacturer, compliance with noise safety ordinances, and as a basis to compare vendor offerings

Sometimes it will be sufficient just to reorient the cooling tower to direct the faces of the cooling tower with higher break out sound away from the problem location, or by creating a barrier between this point and the cooling tower. When this is not enough, various methods and features are available and can be selected by manufacturers to help attenuate the sound from a cooling tower to meet the required levels at the problem location, including, but not limited to:

» Variable frequency drives

» Low sound fans

» Water silencers

» Inlet and outlet attenuators

The manufacturer will choose or advise on a suitable combination of these options to reach the design requirements.

5. OPERATION AND MAINTENANCE

5.1 THE VALUE OF MAINTENANCE

A cooling tower enables building owners and operators to take advantage of the operating cost savings inherent in water-cooled systems. A well-maintained unit empowers the entire system to perform efficiently and reliably, while conserving both energy and water. Owners and operators can save considerable amounts of money through preventative maintenance technology.

Not maintaining systems regularly results in a loss of money every day.

Manufacturers provide a comprehensive maintenance guidance for all of their equipment, which indicate the routines to be carried out periodically.

Table 1: Typical routine maintenance cycles:

Checks and Adjustments	Start up	Weekly	Monthly	Quarterly	Every 6 months	Annually	Shut down
Hot water distribution system	X			X			
Nozzles	X			X			
Cold water basin and basin strainers	X			X			
Operating level and make-up	X		X				
Blow down	X		X				
Belt tension	X		X				
Drive alignment	X					X	
Drive train	X				X		
Gear drive	X	X					
Motor voltage and current	X			X			
Unusual noise and/or vibration	X		X				
General condition	X		X				
Heat transfer section and drift eliminators	X				X		
Combined inlet shields	X			X			
Hot water basin	X			X			
Spray nozzles	X			X			
Fan shaft and axial fan	X			X			
Fan motor	X			X			
Electric water level control package (option)	X				X		
Circulating water quality	X		X				
Fan shaft bearings	X			X			X
Motor bearings	X				X		
Adjustable motor base	X				X		X
Gear drive	X				X		

5.2 IMPORTANT MAINTENANCE OPERATIONS

5.2.1 COLD WATER BASIN

Debris will inevitably make its way into the cooling tower. Therefore, the unit design should facilitate easy debris removal from the basin. A well-designed cold-water basin is sloped toward the strainer to minimise debris accumulation throughout the cold-water basin to avoid under deposit corrosion.

Basins are to be routinely inspected and cleaned as necessary.

Figure 20: Cold water basin

5.2.2. STRAINER

Strainers in the tower provide a means of keeping debris out of the condenser water loop and prevent from reaching the pump. It should be routinely inspected and cleaned as necessary.

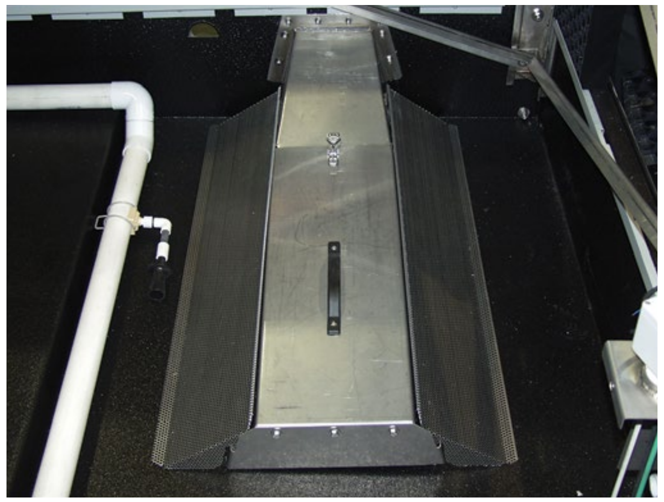

Figure 21: Cold-water basin strainer

5.2.3 WATER DISTRIBUTION

The water distribution system is a key to the cooling tower performance and accordingly need to be maintained properly. The nozzles need to be checked regularly and the clogged nozzles should be cleaned.

Figure 22: Pressurised spray water distribution

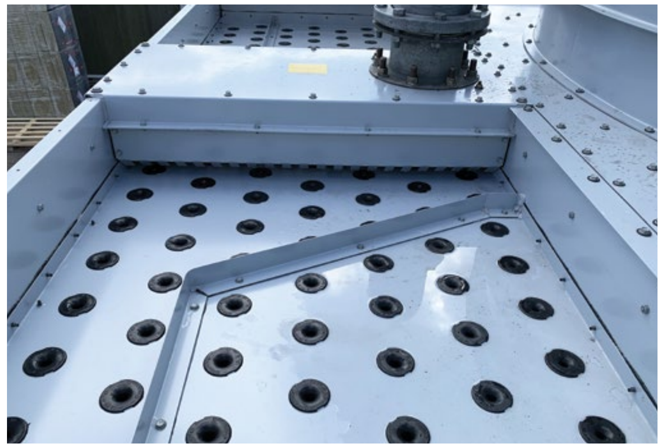

Figure 23: Hot water basin with gravity water distribution

5.2.4 MAKE-UP WATER

The make-up water system adds fresh water via a mechanical float ball and valve assembly, or an electronic water level probe assembly (with solenoid valve) and need to be inspected regularly for proper functioning and to maintain the constant water level in the cooling tower.

Figure 24: Mechanical water level control

5.2.5 BLOW DOWN

To control the build-up of impurities in the recirculation water, the tower should be equipped with a blow down line (including a metering connection and globe valve) connected to a nearby drain. While a manually adjusted blow down valve is the simplest system, getting the proper blow down rate can be a problem, as cooling tower loads vary throughout the day. A conductivity meter connected to a motorised valve solves this problem by constantly maintaining the proper cycles of concentration.

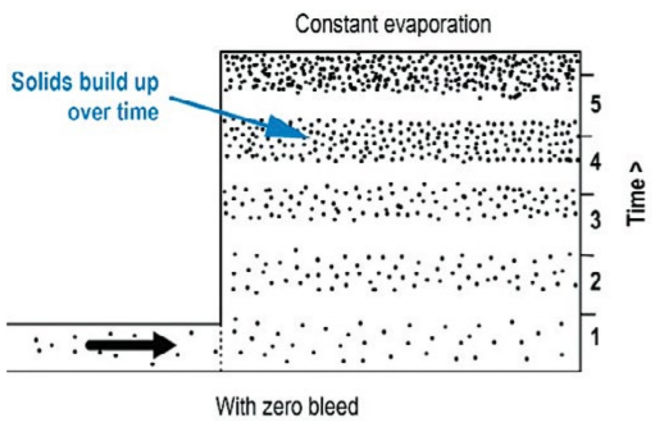

Figure 25: Zero blow down

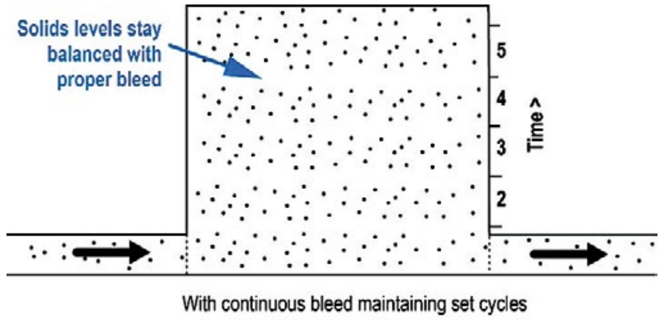

Figure 26: Continuous blow down cycles

5.2.6 FAN DRIVE SYSTEM

Cooling tower fans are typically driven by belt, gear or direct driven systems. All fans require routine maintenance to ensure reliable, trouble-free performance. Belt-driven and gear driven fans need to be inspected and maintained in accordance with the manufacturer's specifications. Direct driven fan systems have lower maintenance requirements as there are no mechanical transmission components, increasing energy savings and reliability.

Figure 27: Greasing the bearing

5.2.7 HEAT TRANSFER SURFACE

The heat transfer area in a cooling tower, being the *fills*, the coil or the combination of both can have problems of *scaling, fouling* and physical damages. Easy access to the heat transfer area for regular inspection (even during operation) is highly recommended. *Fouling* on the *fill* and/or coil will affect heat transfer and the desired outlet temperature.

Figure 28: Heat transfer surface

5.2.8 DRIFT ELIMINATORS

The function of the drift eliminator is to catch the water droplets which are being carried away in the leaving air stream. By creating multiple changes in the direction of the exhaust airflow, centrifugal forces are exerted to the droplets which are carried by the air. In case of excessive drift, examine drift eliminators for proper installation, no gaps between eliminator blocks, and overall condition to ensure there is no clogging or blockage, and check water and air flow.

Figure 29: Drift eliminators

5.3 WATER TREATMENT

A water treatment programme must be implemented to achieve control of corrosion, *scaling,* microbiological growth and *fouling* in the equipment and the cooling system it serves. The growth of algae, slimes and other micro-organisms, if uncontrolled, will reduce heat transfer efficiency and may contribute to the growth of potentially harmful micro-organisms, such as Legionella, in the recirculating water. Maintaining a higher quality of water also allows a user to run at higher *cycles of concentration,* therefore reducing their water costs. Thus, water treatment is also a cost saving component.

Water treatment programmes are crucial to maintain performance and avoid harmful bacteria and biocidal accumulation.

5.3.1 CIRCULATING WATER QUALITY

For optimal heat transfer efficiency and maximum equipment life, the quality of the make-up and recirculating water should be maintained within the limitations as per the manufacturers water quality guidelines (typical information below).

Table 2: Water quality recommendation:

Property of water	Recommended levels for various materials of construction		
	Galvanised steel	Type 304 stainless steel	Type 316 stainless steel
pH	6,5-9,0 [1]	6,5 to 9,2 [1]	6,5 to 9,5 [1]
Total suspended solids	25 ppm	25 ppm	25 ppm
Total dissolved solids (TDS)	1.500 ppm		
Conductivity	2.400 (microohms/cm)	3.300 (microohms/cm)	4.000 (microohms/cm)
Alkalinity as $CaCO_3$	500 ppm [2]	600 ppm [2]	600 ppm [2]
Calcium hardness as $CaCO_3$	50-600 ppm [2]	50-750 ppm [2]	50-750 ppm [2]
Chlorides (CL)	250 ppm	300 ppm	750 ppm
Sulphates	250 ppm	350 ppm	750 ppm
Silica	150 ppm	150 ppm	150 ppm

5.3.2 SCALE FORMATION

Excessive *scaling* on the heat transfer surfaces within an evaporative cooling product greatly reduces heat transfer efficiency and could even destroy its structure. This can result in higher cooling temperatures than designed and eventually system down-time. Scale formation always causes higher energy consumption, and this applies all year round regardless of the load on the system. Whilst scale itself is not considered as a nutrient for bacteriological growth, heavy scale formation provides a breeding haven for micro-organisms and can therefore add to the risk of bacteriological contamination.

Depending on the main supply water and system operation, scale formation can be prevented by the correct combination of softening of the *make-up water*, control of pH and bleed-off and dosing of scale inhibitor chemicals. Physical methods for controlling scale such as electro-magnetic or ultrasonic techniques and others are also available. The control of scale needs to be carefully evaluated on a case-by-case basis.

5.3.3 CORROSION

Premature or rapid corrosion is detrimental to the cooling system components and may shorten equipment life considerably. Corrosion by-products, such as iron oxides, can furthermore encourage bacteriological growth. For these reasons corrosion within a cooling system should be minimised at all times. To achieve this the water quality must be kept within the limits specified by the supplier of system components and, in many cases, the dosing of a chemical corrosion inhibitor as well as the control of the pH value is recommended.

5.3.4 BIOCIDAL CONTROL

Proper operation, *blow down* and chemical water treatment for scale and corrosion are not a guarantee of controlling bacteriological growth in a cooling system. Therefore, specific attention must be given to the matter of bacteriological control. There is a wide range of systems, which allow control of microbiological growth (including Legionella). A water treatment specialist should advise on the best biocidal treatment for a particular cooling system.

5.3.5 LEGIONELLA

Legionnaires' disease is a rare but serious form of pneumonia. Legionella, the bacteria, which causes the disease, is commonly found in surface water such as ponds and rivers. Only some species of the bacteria, such as *Legionella Pneumophila,* can become harmful to humans. t is likely to exist in low concentration in many water systems.

While low concentrations are harmless, water stagnation can lead to an accumulation of bacteria and thus should be avoided in the complete condenser water circuit. Various measures can be introduced to eliminate the risk of legionella occurrence in a cooling tower's water system.

- The tower basin should avoid water stagnation. Basins should be sloped towards a drain connection to allow proper drainage.
- The piping must be self-drainable or drainable, and dead legs should be avoided.
- Water distribution systems should be designed in a way that they can drain fully, when the water supply is stopped.
- The equalising lines for multiple cell installations should be kept as short as possible to reduce water volume to minimise water stagnation potential.

5.3.6 FOULING

Fouling of heat exchange surfaces due to dirt, sludge and slimes in the system will not only affect thermal performance but may also encourage the growth of bacteria. In open cooling towers, for example, it even may destroy the *fill* pack. Therefore, steps must be taken to avoid a build-up of dirt and debris within the cooling tower and the rest of the system.

For systems with dirty water or where significant amounts of airborne dirt and debris are carried into the system, filtration of the recirculating water may be needed. Usually this is side stream type where a portion of the water is drawn from a water collection basin, filtered and then returned to the system.

Sometimes silt and sludge can be controlled with chemical bio dispersants, which are either dosed separately or blended with a chemical biocide.

5.4. FILTRATION AND ENVIRONMENTAL INFLUENCES

5.4.1. WATER FILTRATION

It is recommended to install an effective water filtration system in cooling towers. Effective filtration systems achieve the following:

- Extend the life of your cooling system and offers a quicker return on the investment (payback period usually 12-18 months)
- Reduce the risk of Legionnaires disease outbreaks
- Maintain optimum heat transfer efficiency in heat exchangers
- Reduce expenses for chemical treatment programmes, maintenance and cleaning costs, and downtim

5.4.2 SEPARATORS

Separators apply centrifugal action to remove solids that are heavier than water, with filtration performance ranging from 5µm to 75µm. The pressure loss is low and steady with minimal maintenance requirements; no moving parts, only periodic inspection / servicing, none to minimal liquid loss.

5.4.3 SAND FILTERS

Sand filters are best for removing fine particles and best to be avoided for coarse particle applications. The pressure loss is low and may vary with a need for more regular maintenance, periodic back washing and inspections, sand replacement and potentially excessive liquid loss

Figure 30: Aluminium fan inside fan stack

5.4.4. BASIN SWEEPER PIPING

Filtration directed specifically at the control of solids accumulation in the cooling tower basin is relatively new to the HVAC industry. However, this approach ensures the solids are diverted to the filtration system, which eliminates build-up of solids in the tower preventing dirt from reaching the heat exchange surfaces (plate heat exchangers / condensers). Basin sweeper piping is among the most popular and effective filtration approaches in use today.

Figure 31: Basin sweeping piping

5.5 CONCLUSION

Paying regular attention to the forgotten system component, the cooling tower, through a regular, comprehensive maintenance programme can save time, money and energy while increasing the tower's life expectancy.

> **Comprehensive maintenance programmes save money.**

Figure 32: Mechanical drive system

6. PRODUCT SAFETY, QUALITY AND COST CONSIDERATIONS

The selection of a cooling tower depends on many parameters such as wet bulb temperatures, space, water *outlet temperature*, waterflow, etc. Questions of materials, design and maintenance are key to a durable, cost saving and healthy unit. **Thus, quality should always be considered before cost.**

To maintain peak performance, the equipment should allow easy maintenance and safe access to all the components. Hence the design of the cooling tower should include all aspects described above to minimise corrosion, build-up of scale and mould, biocidal growth and allow easy access to all components for maintenance, especially to the areas requiring regular inspections and maintenance.

Neglecting the cooling tower will lead to higher than desired return water temperatures to the system, which will result in higher energy usage from two perspectives. First, the system (chiller) will consume more energy because it must operate at a higher than necessary condensing pressure to satisfy the load due to the higher fluid temperatures provided by the cooling tower. As little as 1°C higher temperature can result in 3% more energy being consumed by the chiller. Second, the tower must operate longer at higher fan speeds while trying to attain the design cold water temperature.

Another way of keeping the process system clean (especially for Industrial applications, data centres and high reliability systems) is to evaluate closed loop technology. *Closed circuit* cooling towers completely isolate process cooling fluid from the atmosphere. A closed loop system protects the quality of the process fluid, reduces system maintenance, and provides operational flexibility.

6.1 MATERIALS OF CONSTRUCTION

Various materials of construction can be used in cooling towers, for the structure and components. The correct selection of these materials will depend on the size, *make-up water* quality, environmental conditions and service life required for the equipment. A full evaluation should always be undertaken to ensure the materials being specified are suitable for any project.

In package sized cooling towers the most commonly used structural materials would be galvanised or stainless steels (304 or 316 are most common), and fibre reinforced polyester (FRP). Sometimes coatings or paints can also be used on the surface of the steel. In field erected sized cooling towers structural materials would more commonly be FRP, steel and concrete.

Cooling tower internal components can be made from various materials, again often depending on the water quality and component life requirements. Material specifications should always be considered to ensure the correct quality of materials are used for the expected lifespan.

6.2 CONCLUSION

Cooling towers can provide significant savings, if specified, designed, built, operated and maintained correctly. Any compromise on quality in these areas will unmistakably lead to higher operating costs and shorter lifespan of the units, ultimately setting off any gains by a cheaper purchase price.

> **Quality should never be compromised by questions of costs. Remember, cheap is always more expensive.**

From all the chapters above, one can evaluate a good product and a quality manufacturer by asking the following questions:

- Is the manufacturer experienced with local conditions?
- Is guidance offered by the manufacturer for a project?
- Does the product fulfil all requirements in terms of maintenance (access, materials, design)?
- Is an independent certification provided?

7. COOLING TOWER CERTIFICATION

Cooling towers are a crucial part of a cooling system and designers and buyers need to rely on published thermal capacity performance data provided by the manufacturer. To ensure that claims and real-life performance are in line, independent third-party certification by accredited organisations is important.

Additionally, minimum energy efficiency standards like the Eurovent Recommendation 9/12 or ASHRAE 90.1, which are used by governments and green building certification programmes such as LEED™, require the independent verification of a cooling tower's energy efficiency according to CTI STD 201.

Independent third-party certification is essential to avoid discrepancies between published performance data and actual performance.

The two globally recognised certification programmes are run by CTI (Cooling Technology Institute, Houston, TX, USA) and Eurovent (Eurovent Certification, Paris, France). Both organisations are certifying based on the standard CTI STD 201 and are recognised by each other. Thermal performance certification via this programme offers a tower buyer assurance that the capacity published for the product has been validated and confirmed by the initial and ongoing performance testing as required by the certification programme.

While field erected towers usually are certified after the installation, standardised models are subjected to an ongoing and recurrent certification programme.

Factory assembled products with CTI/Eurovent certification do not require any further testing on site.

7.1 EUROVENT CERTIFICATION PROGRAMME

Scope:	Open and Closed-Circuit Cooling Towers
Requirements:	Annual factory audit, one unit per range tested by independent laboratory
Technical Certification Rules:	ECP-04 CT

All certificates should always be cross checked with the certifier's database to ensure the validity of the certificate provided. Eurovent Certification provides free access to its database with a product search engine at www.eurovent-certification.com.

Eurovent certificates shall be cross checked with an online database to ensure their validity.

GLOSSARY

Terminology	Definition
Adiabatic coolers	Equipment used to transfer heat from a process to the atmosphere by lowering the temperature of the entering air by humidification, with constant enthalpy
Air inlet louvers	Devices installed at the air inlet to minimise splash-out and exposure of the basin water and heat transfer media to sunlight
Blow down	Water discharged from the system to control the concentration of salts or other impurities in the circulating water
Closed circuit cooling tower	Equipment in which the process fluid circulates inside a heat exchanger which is cooled by water circulating in direct contact with air
Counter flow	Where air flows in a counter current to the water flow within the evaporative cooling device
Cross flow	Where air flows perpendicularly to the water flow within the evaporative cooling device
CTI (Cooling Technology Institute)	An organisation comprised of evaporative cooling equipment owners and operators, equipment manufacturers, component suppliers and water treatment specialists, which advocates and promotes the use of environmentally responsible evaporative heat transfer systems for the benefit of the public through education, research, standards development, government relations and technical information exchange
Cycles of concentration	Ratio of the concentration of elements in the circulating water compared to the concentration in the makeup water
Entering wet bulb temperature	Wet bulb temperature of the air entering the cooling tower or evaporative condenser, including the effect of any recirculation and/or interference
Equalising lines	Connecting pipes between multiple cooling tower cells operating in parallel with the aim to establish a common operating water level in all cells, usually required only with open cooling towers
Evaporation loss	Amount of water evaporated into the atmosphere during the heat transfer process
Fill	Medium that is used in cooling towers to increase the surface area available for water evaporation, also known as wet deck
Fouling	Deposit of suspended solids inside the installation in combination with biological activity, causing loss of efficiency
Hybrid cooling tower	Apparatus incorporating two modes of heat transfer operating simultaneously, wet and dry with the aim to reduce water consumption and/or to reduce or eliminate the visibility of the plume; hybrid cooling towers are closed-circuit type
Induced draft	Location of the fan(s) on evaporative cooling equipment; on induced draft equipment the fans are located on the air discharge side of the equipment to induce air through the unit
Legionella Pneumophila	The most virulent Legionella bacteria causing Legionnaire's disease, which is a rare and severe form of pneumonia
Mechanical draft cooling tower	Cooling tower where the air circulation is produced by a fan
Make-up water	Water added to the system to replace water lost by evaporation and blow down, as well as drift, leakage and splash-out losses
Open circuit cooling tower	Apparatus where in the process fluid is warm water which is cooled by the transfer of mass and heat through direct contact with atmospheric air
Outlet temperature	Temperature of the fluid leaving the cooling tower
Plume abatement coils	Finned coils integrated into the evaporative cooling device with the aim to reduce or eliminate visible plume by warming part or all of the discharge air moved through the device, can be integrated into the process fluid cycle or fed by external heat sources
Recirculation	Situation that occurs when the warm discharge air flows back into the air inlets of the evaporative cooling equipment; to avoid recirculation, layout guidelines provided by equipment manufacturers should be closely followed
Scaling	Deposit of oversaturated dissolved solids (calcium carbonate scaling is the most common one)
Sump	Cold-water basin of the evaporative cooling equipment

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This is the second edition of this Guidebook. For comments, input and corrections, kindly get in touch with the Eurovent Middle East Secretariat: office@eurovent.me.

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NOTES

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