A SunCam online continuing education course

HVAC Design – Cooling Towers

by

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INTRODUCTION

This course in Cooling Tower selection, sizing, and system design will benefit design professionals such as engineers, architects, and designers, as well as those involved in facility management and maintenance. Upon completion of this course, you will have a better understanding of the principles involved in cooling tower sizing and selection as well as the design of related systems.

COOLING TOWER OPERATING PRINCIPLES

Natural bodies of water such as rivers, lakes, and streams are important parts of our landscape. Besides their natural beauty, they provide many benefits such as recreation and transportation. They contribute to our water supply and they're an integral part of the earth's ecological system. Natural bodies of water are also heat exchangers. Every year as the hot summer months give way to cooler fall temperatures, natural bodies of water release heat into the atmosphere. In this way, natural bodies of water can be characterized as air-to-water heat exchangers.

Figure 1: Lake

Cooling towers share a common trait with natural bodies of water. While you can't fish or swim in them, and only a mechanically-minded person might find one beautiful, cooling towers are air-to-water heat exchangers. Perhaps they make up for their other shortcomings by doing a much better job of it.

Figure 2: Cooling Tower

Cooling towers were invented around the turn of the century for use in conjunction with steam engines. In urban settings where natural bodies of water are sometimes limited, cooling towers were used to recycle cooling water pumped through steam engines to condense the steam exhaust back into water. This had the effect of reducing backpressure, which in turn improved fuel economy. Early cooling towers were tall structures built to maximize the amount of time that the water came in contact with the air.

Imagine for a moment that you are an engineer at the turn of the century working for a large textile mill. Your most important charge is overseeing the operation of the steam engine that powers the entire facility. Management has tasked you with making improvements to the steam engine's cooling tower which consists of a 20 foot tall structure that sits atop the building. The cooling tower is constructed of bricks that are arranged in a staggered pattern to allow air to pass between the openings. The hot water return runs up a 4 inch pipe to the top of the tower. At the bottom is a basin where the cool water collects before being supplied back to the steam engine. You know that increasing the amount of time that the water comes in contact with the air will result in the desired effect of reducing the basin water temperature, but the tower is already built as tall as it can go. What else can you do to improve the cooling tower's performance?

What if instead of relying on the air to enter the tower naturally, you forced it in with a fan? That would increase the quantity of air that comes in contact with the water. And what about the stream of water itself? Is there any way to spread it out to increase its surface area? What if instead of having the water fall through the tower in a single stream, you install a series of nozzles at the top so it sprays out like a shower? You get busy implementing those changes and measure the basin water temperature. You're pleased to find that the water in the basin is significantly cooler than it was before. You wonder if there is anything else you can do. What if you could slow down the water as it fell through the tower? As a test, you have pieces of pipe installed horizontally through the openings in the brick structure. Your theory is that as the water sprays into the tower the droplets will hit the pipes like a ball draining down a pinball machine. Not only will the flow of water be slowed thereby increasing its contact time with the air, but you will reap the added benefit of breaking the water into even smaller droplets which increases the surface area. When you measure the basin water temperature again, you find that it's decreased even further. Congratulations, you've just invented the modern cooling tower.

All heat exchangers have one thing in common: the warm fluid leaves the heat exchanger cooler than when it came in, and the cool fluid leaves the heat exchanger warmer than when it entered. In a cooling tower, the water enters warm and leaves cooler, and the air enters cool and leaves warmer. The water leaving a cooling tower will never be as cool as the air entering the tower, but it comes close. The difference between the leaving water temperature and the entering air wet bulb temperature is called the *approach*. The difference between the entering and leaving water temperatures is called the *range*. Refer to Figure 3 for a graphical representation of this terminology which includes sample values.

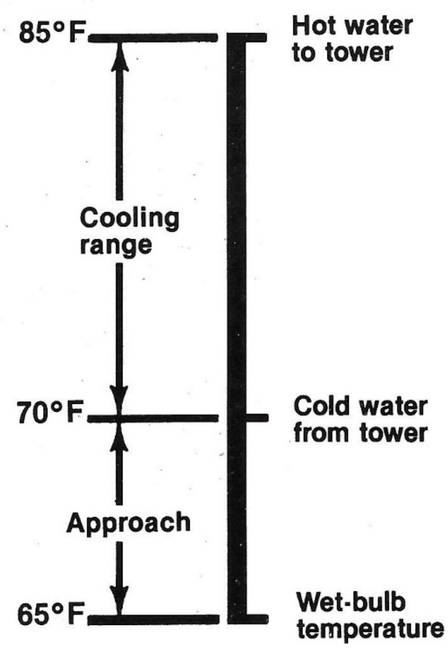

Figure 3: Cooling Tower Range and Approach

One bit of cooling tower terminology that many people find confusing is the notion that a ton of cooling tower capacity is equal to 15,000 BTUs per hour. We all know that a ton of cooling is equal to 12,000 BTUs per hour, so how can a ton of cooling tower capacity equal 15,000 BTUs per hour? The answer lies in the ASHRAE handbook. It states that the 15,000 BTUs per hour per ton of cooling tower capacity comes from the assumption that 3,000 BTUs of compressor heat must be dissipated for every ton of air conditioning. That seems a little presumptuous. When specifying cooling towers, it is advisable to steer clear of this terminology and define cooling tower capacity by the difference between the entering and leaving water temperatures at a specific GPM and ambient wet bulb temperature. This will avoid any confusion on the part of equipment providers and contractors.

COOLING TOWER TYPES

Types of cooling towers include direct and indirect, counterflow and crossflow, mechanical draft and natural draft, induced draft and forced draft, and factory assembled and field erected. There are a number of other classifications and terms but they come down to a matter of referring to the same thing by different names. We will examine each type of cooling tower and address the synonyms along the way.

DIRECT AND INDIRECT: In a *direct* cooling tower (also known as *open* and *evaporative*), the water being cooled comes in direct contact with the air. Most cooling towers are direct cooling towers. The primary advantage of a direct cooling tower is that as a byproduct of the heat transfer that takes place between the water and air, some of the water evaporates. This evaporation is responsible for most of the cooling effect that takes place.

The hot water as it enters the cooling tower is forced through spray nozzles which increase the water's surface area. Then the water cascades over fill to slow its rate of flow though the cooling tower and further break up the water droplets. This has the effect of increasing the air-to-water contact time and surface area. *Fill* is typically constructed of PVC and is designed to slow the travel of water through the cooling tower.

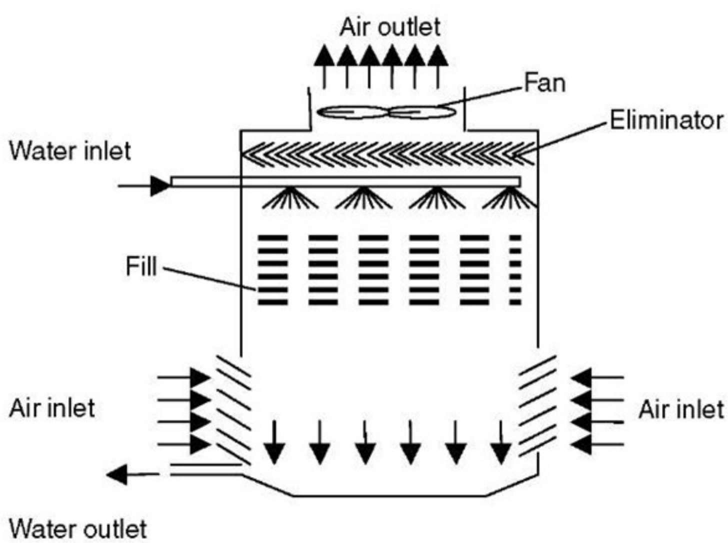

Figure 4: Direct Cooling Tower Diagram

As the name implies, in an *indirect* cooling tower (also known as *dry* and *closed circuit*) the water being cooled is not directly exposed to the atmosphere. Indirect cooling towers are used when there is a reason not to expose the fluid being cooled, such as a concern about contamination – either the atmosphere contaminating the fluid, or the fluid contaminating the atmosphere. Indirect cooling towers are most often used in process applications. The fluid being cooled travels in a closed circuit through the cooling tower where an external water source is sprayed over the closed circuit piping. Heat transfer occurs between the fluid being cooled and the external water source through the walls of the closed circuit piping.

There is an added level of inefficiency inherent with indirect cooling towers when compared to direct cooling towers. Recall that a warm fluid leaving a heat exchanger never gets as cold as the cool fluid entering the heat exchanger. There will always be a temperature difference which in cooling tower vernacular is referred to as the approach. Since an indirect cooling tower is essentially a heat exchanger wrapped inside of another heat exchanger, there are limitations when applying them. In other words, since the design atmospheric wet bulb temperature of the project's locale is fixed, there is an entering water temperature limit below which the cooling tower will not achieve its objective.

Let's look at an example. Suppose you have a cooling application for a candy factory located in Jacksonville, Florida. You need to cool chocolate from 110° F to 85° F and the candy cannot be exposed to atmosphere due to concerns about product contamination. According to ASHRAE, the 1% design wet bulb temperature for Jacksonville is 77° F. The indirect cooling tower you specify has a 6° F approach on the external water side and another 4° F approach on the closed circuit side.

$$6° \text{ F} + 4° \text{ F} = 10° \text{ F} + 77° \text{ F} = 87° \text{ F}$$

When the external approach is added to the internal approach, the result is 10° F of separation between the incoming air wet bulb temperature and the outgoing product temperature. When this is applied to our locale, we find that 87° F is as cold as the chocolate can get. That's what is meant by application limitations inherent with the use of indirect cooling towers. As an aside, chocolate is generally cooled with liquid nitrogen or mechanical refrigeration, not with a cooling tower.

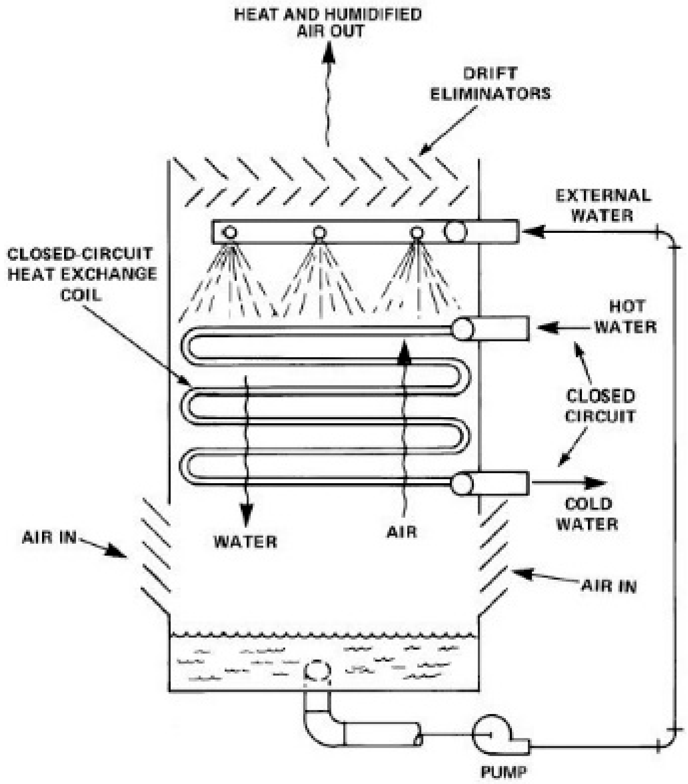

Figure 5: Indirect Cooling Tower Diagram

COUNTERFLOW AND CROSSFLOW: In a *counterflow* cooling tower, both the air doing the cooling and the water being cooled travel in a vertical direction. The water enters at the top of the tower and falls by gravity to the bottom. The air enters near the bottom the tower and is forced out of the top by the fan. Figures 4 and 5 both depict counterflow cooling towers.

In a *crossflow* cooling tower, again the water enters at the top of the tower and falls by gravity to the bottom, but the air enters through the side of the tower and travels perpendicular to the water flow.

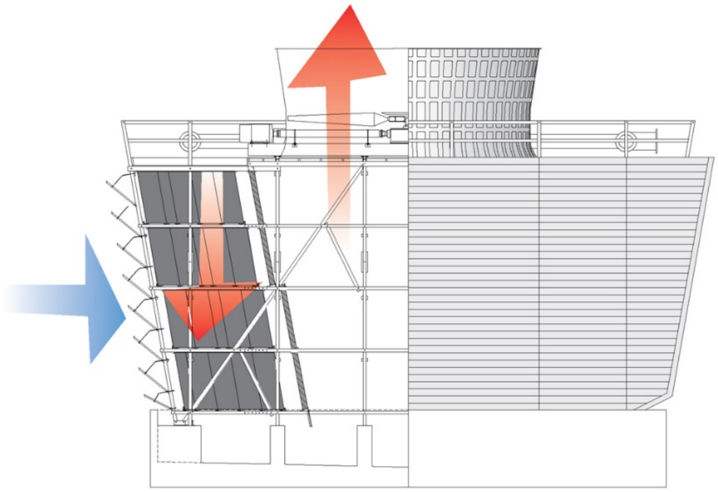

Figure 6: Crossflow Cooling Tower

When considering counterflow versus crossflow, it's primarily a function of which cooling tower manufacturer you choose. Some cooling tower manufacturers design their equipment based on counterflow while others base their design on crossflow. Perhaps it would be helpful if we think of a cooling tower as a closed boundary system or simply a generic machine. We send hot water and electricity to the cooling tower and it sends back cool water. It's not as simple as that, but suffice it to say that as it regards counterflow versus crossflow, the considerations for the design professional are somewhat limited.

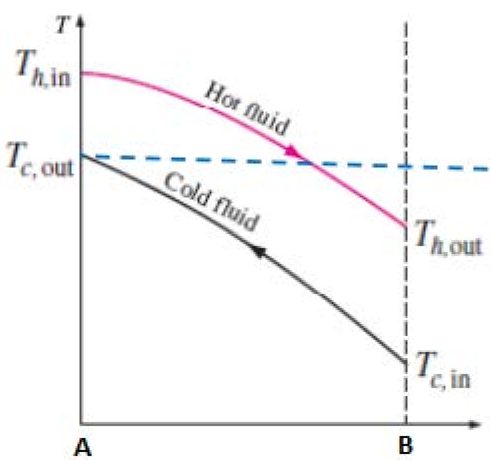

Figure 7: Counterflow Cooling Tower

From a purely technical standpoint, a counterflow heat exchanger is more efficient than a crossflow heat exchanger. Refer to Figure 7. You can see that in a counterflow design, the hot fluid is at its hottest (water as it enters the cooling tower) when it is exposed to the cold fluid at its warmest (air as it leaves the cooling tower). The efficiency of the design enables the hot fluid leaving temperature, $T_{h\ out}$, to be suppressed beneath the cold fluid leaving temperature, $T_{c\ out}$.

MECHANICAL DRAFT AND NATURAL DRAFT: A *mechanical draft* cooling tower (also known as *conventional*) has one or more fans to move the air. Figures 2, 4, 5, and 6 depict mechanical draft towers.

A *natural draft* cooling tower (also known as *atmospheric*, *hyperbolic*, and *chimney*) does not have a fan. Natural draft cooling towers take advantage of the fact that hot air rises. This is referred to as the *stack effect*. The stack effect in a natural draft cooling tower begins when cool atmospheric air enters near the base of the tower and mixes with hot water. The air is heated and it naturally rises to the top. As it does, it pulls in more cool air near the base of the tower. With a natural draft cooling tower, there is no fan to buy, no energy expended to run the fan, and no maintenance on the fan.

One might imagine that every cooling tower must be a natural draft design because they have so many advantages. Actually, the opposite is true. Mechanical draft cooling towers are by far the most prevalent. This is due to the fact that in order to produce the stack effect, the tower must be of considerable height. Some natural draft towers are over 500 feet tall. Natural draft cooling towers are almost exclusively used in electrical power generation plants. Utility companies have deep pockets and a long view when it comes to acceptable return on investment. Not to mention that power plants are often located in rural areas where there are few people to complain about the way they look.

Figure 8: Natural Draft Cooling Tower at Power Generation Plant

INDUCED DRAFT AND FORCED DRAFT: The terms *induced draft* and *forced draft* as they relate to cooling towers refer to the manner in which air is moved through the tower. In an induced draft cooling tower, the fan pulls air out of the unit which induces a draft. Induced draft cooling towers are characterized by high air exit velocity, low air entrance velocity, and propeller fans which have little or no static capability. Figures 2, 4, 5, and 6 depict induced draft cooling towers. Most cooling towers are induced draft.

In a forced draft cooling tower, the fan is positioned so that it directs air into the unit. Forced draft cooling towers are characterized by low air exit velocity, high air entrance velocity, and many use centrifugal fans which have a high static capability. Forced draft cooling towers are indicated when an application calls for the cooling tower to be located inside a building.

Building-interior cooling tower installations require the air to be ducted to and from the tower, which forced draft cooling towers with centrifugal fans are equipped to do.

Figure 9: Forced Draft Cooling Tower

FACTORY ASSEMBLED AND FIELD ERECTED: It may come as no surprise that a *factory assembled* cooling tower is assembled in a factory, and a *field erected* cooling tower is erected in the field. A factory assembled cooling tower (also known as *packaged* and *unitary*) is a cataloged piece of equipment that is delivered to the jobsite on the back of a truck. The advantage to a factory fabricated cooling tower is that it's much less expensive when compared to a field erected cooling tower. Most cooling towers are factory assembled. Figures 2, 9, and 16 depict factory assembled cooling towers.

A field erected cooling tower is fabricated in the field because it's too large to be shipped on a truck.

Figure 10: Field Erected Cooling Tower

COOLING TOWER MECHANICAL APPLICATIONS

Cooling towers are used in HVAC applications, industrial processes, and power generation. Because the scope of this course is limited to HVAC design, the balance of the text will focus on HVAC applications. The most common type of cooling tower used for HVAC applications is a mechanical induced draft factory assembled unit. As mentioned previously, counterflow versus crossflow is primarily a function of which cooling tower manufacturer is selected.

The primary purpose of a cooling tower used in an HVAC application is to reject condenser heat to the atmosphere. The two most common applications are water-cooled chillers and self-contained units. In a chilled water system with a water-cooled chiller, condenser heat is rejected via a cooling tower.

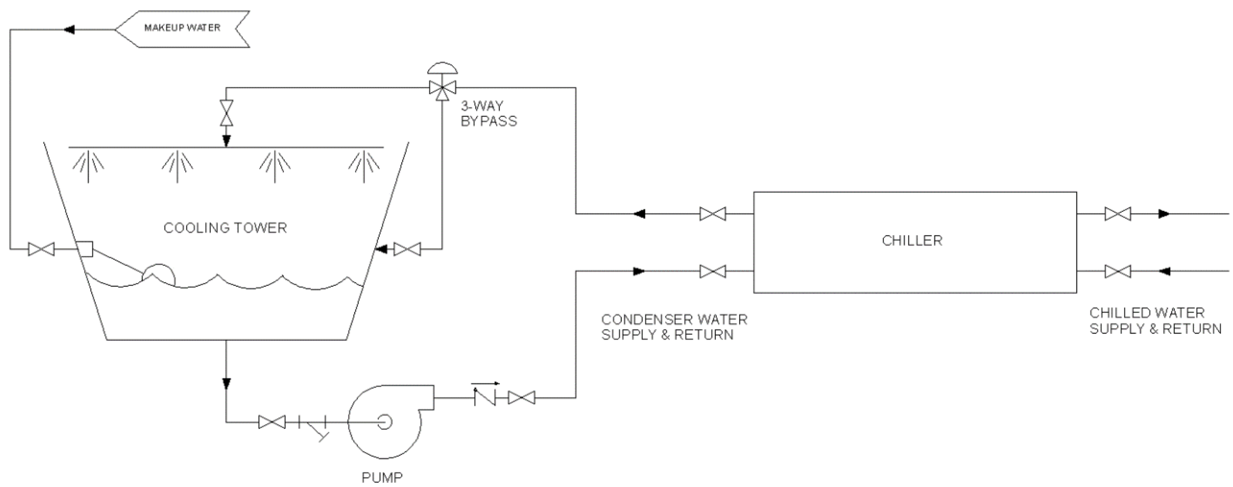

Figure 11: HVAC Cooling Tower Application: Water-Cooled Chiller

Figure 11 depicts a cooling tower serving in a water-cooled chiller application. In HVAC applications, water flowing through the cooling tower is often referred to as *condenser water* because that is its purpose. The condenser resides in the water-cooled chiller, so from the chiller's perspective cool water flowing into the condenser is *condenser water supply* and the hot water leaving the condenser is *condenser water return*. Let's step through Figure 11 in detail.

Cool condenser water collects in the cooling tower basin and a mechanical float valve adds fresh water as needed based on the basin water level. The condenser water pump pulls condenser water from the cooling tower basin through a strainer and a shutoff valve. On the discharge side of the pump, condenser water is pushed through a check valve and shutoff valves on through the condenser barrel of the water-cooled chiller. The chiller's condenser heat is transferred to the condenser water and the hot condenser water returns back to the cooling tower. On it's way to the cooling tower, the condenser water encounters a 3-way bypass valve. The purpose of the 3-way bypass valve is to allow the condenser water to partially or completely bypass the cooling tower and go straight into the cooling tower basin. This becomes necessary during periods of cool weather in order to modulate the cooling tower capacity. Under the pressure of the condenser water pump, the condenser water is sprayed into the top of the cooling tower where it comes into contact with the airflow provided by the fan. The flow of water is slowed by the cooling tower fill before it collects in the basin and the cycle begins all over again.

In cold climates, the cooling tower can provide free cooling. The chiller is shut down when the cooling tower's capacity is sufficient to meet the building cooling load. This is typically accomplished with automatic control valves and a plate and frame heat exchanger. The purpose of the heat exchanger is to keep the condenser water separate from the chilled water. Because it is exposed to the outdoors, condenser water is dirty and if it were used directly in the chiller without the heat exchanger keeping the flows separate, the condenser water would foul the chilled water side of the chiller and the air-handling unit chilled water cooling coils.

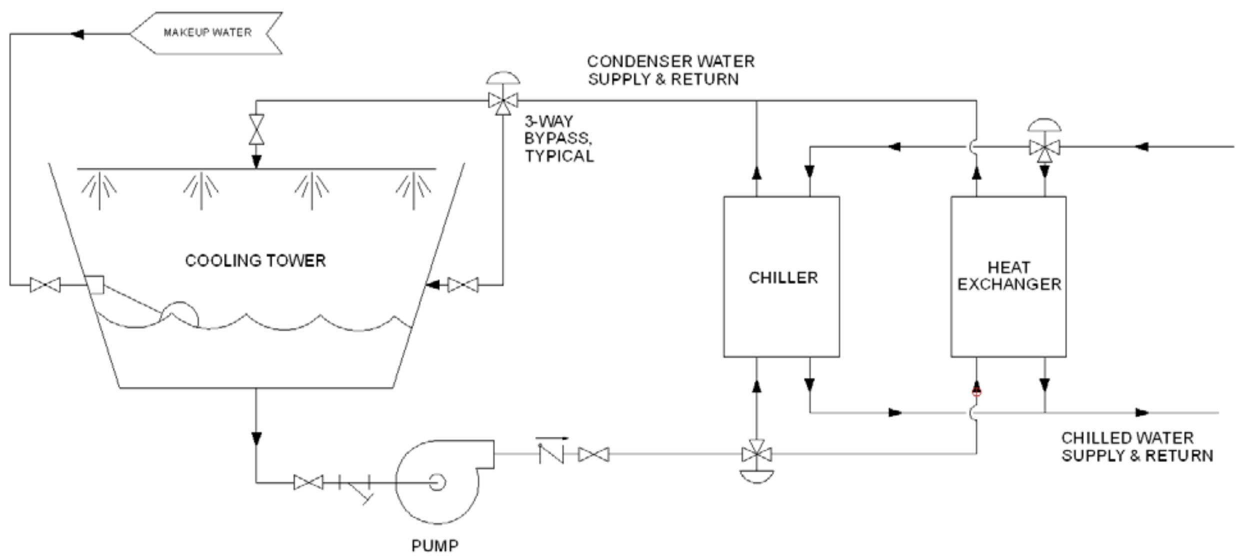

Figure 12: HVAC Cooling Tower Application: Free Cooling Arrangement

Self-contained mechanical units are direct expansion systems with the compressor located in the indoor air-handling unit. Because the compressors are located indoors, self-contained units need a means to reject the heat of compression. Figure 13 depicts a typical piping arrangement for a cooling tower used in conjunction with a self-contained unit.

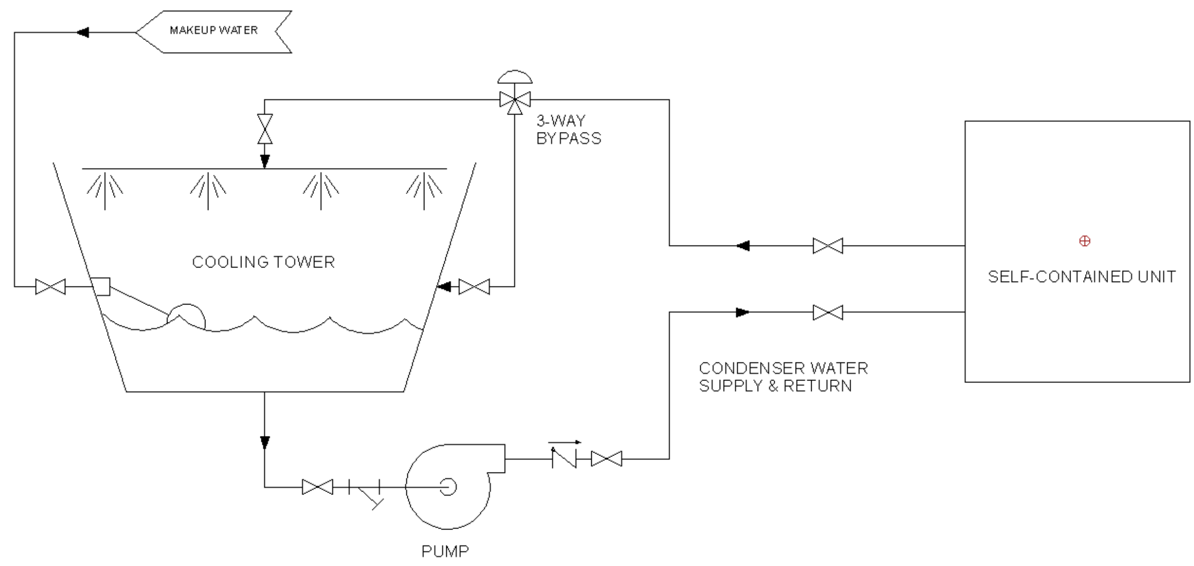

Figure 13: HVAC Cooling Tower Application: Self-Contained Unit

COOLING TOWER SIZING

As discussed earlier, cooling tower capacity is best defined by the difference between the entering and leaving water temperatures at a specific GPM and ambient wet bulb temperature. Listed below is a sample of cooling tower selection criteria:

ENTERING WATER TEMPERATURE, °F:	95
LEAVING WATER TEMPERATURE, °F:	85
AMBIENT WET BULB TEMPERATURE, °F:	77
FLOWRATE, GPM:	1,200

This is all of the information that is needed to size a cooling tower. Packaged cooling towers are designed by cooling tower manufacturers, not by those who specify them. You're not going to be deciding on the number of spray nozzles or how to arrange the tower fill. Again, that is done by the cooling tower manufacturer. For a typical construction project, the mechanical design professional will take the information listed above and schedule it on the drawings, then he or she will pick up the phone and call their favorite cooling tower representative. The vendor rep will make a selection and email the cutsheet. Alternatively, you can make your own selection using published literature available from the cooling tower manufacturers.

It's a simple matter but important to note that the terms *entering* and *leaving* are always from the equipment's perspective. For example, the leaving condenser water temperature for a cooling tower is the entering condenser water temperature for a water chiller.

You might ask how one arrives at the entering and leaving water temperatures and flowrate. Those values are based on the requirements of the equipment being served. For example, to size a cooling tower for a water-cooled chiller application, one would look in the chiller literature for the condenser water flowrate and design entering and leaving condenser water temperatures. The literature will also specify minimum and maximum allowable condenser water entering temperatures. Similarly, for a self-contained unit, the condenser water requirements will be specified in the manufacturer's published literature.

On projects with multiple water-cooled chillers or self-contained units, the condenser water flowrate is based on the sum of the flowrates of all of the connected equipment. There are a number of strategies for dealing with multiple pieces of mechanical equipment. When possible, the strategy employed should be based on input from the owner. By *owner*, we mean the business entity who contracts with the architects and engineers and contractors to design and build a facility. Some owners are very sophisticated and they have their own engineers and project managers who have very specific opinions about what strategy should be employed for applications with multiple pieces of equipment. Other owners are not as sophisticated and they rely on the design professional to use their best judgment.

One strategy for dealing with multiple pieces of mechanical equipment is to use a one-to-one relationship. For example, if the project has 6 water-cooled chillers, then it gets 6 cooling towers. This strategy makes the controls very simple. If a chiller shuts down, it's associated cooling tower shuts down. The downside of this strategy is depending on the number of chillers on a project, you could end up with a large number of cooling towers. Another strategy is to base the sizing on two units and select an acceptable percentage of the total required capacity in the event that one unit fails. For example, you might reason that during most of the year the cooling load can be met with a capacity equal to 75% of the peak capacity, so you specify 2 cooling towers each with a capacity of 75% of the total load. The disadvantage of this strategy is that the owner ends up buying 150% of the required capacity. Still another strategy is n+1. This strategy is based on the premise that if any one unit fails, 100% of the required capacity will still be provided. For example, if the total required condenser water flow is 9,000 GPM, the application would have 4 cooling towers each with a capacity of 3,000 GPM.

On some projects the design professionals are expected to arrive at preliminary equipment sizes in a very short period of time. This is often required on design/build projects in order to provide the owner with a cost estimate. Even if it is not a project requirement, it's a good idea to go through the exercise in order to allocate space for the mechanical equipment. Architects need this information early in a project to design the floorplan. In doing a preliminary design, there typically isn't time to go through all of the required design steps and contact all of the vendor reps. The best approach is to employ established rules of thumb to arrive at preliminary equipment sizing. That way you can do it in a matter of hours or days rather than weeks or months. A useful rule of thumb for preliminary design is 1 GPM of condenser water for every 100 Sq. Ft. of air-conditioned space. This is based on an estimated cooling load of 300 Sq. Ft. per ton and a condenser water flow of 3 GPM per ton.

COOLING TOWER SITING AND LOCATION

Unless you enjoy designing the mechanical layout over and over again, it's a good idea to make the process of locating the cooling tower a collaborative effort. The mechanical design professional should arrive at a preliminary size early in the project and hold a meeting to discuss the cooling tower location. The architect will have a keen interest in its location, as will the structural and civil engineers. Cooling towers are big, ugly, noisy machines which – depending on the time of day and season – can emit huge plumes of fog. The potential to generate fog is a good reason not to locate a cooling tower near a road or a highway. Placing a cooling tower near a property line can also create issues. It's a good idea to check local noise ordinances before selecting the cooling tower location.

Since moisture from a cooling tower can condense in the atmosphere, wherever possible it's a good idea to locate the cooling tower at a high level in order to avoid creating a nuisance. For structures more than one story in height, the roof is a good location. To avoid putting too much weight on the roof, cooling towers can be configured with remote sumps. Instead of the water collecting in the cooling tower basin, it's piped to a remote sump at or below grade. For single story applications, the cooling tower can be located along the back of the building near other unsightly objects such as the power entrance or trash.

Cooling towers must not be located any closer to an obstruction or interference than allowed by the manufacturer's published literature. An interference can be a wall beside a cooling tower or a structure located above it or anything that interferes with air freely entering and leaving the cooling tower. Inadequate clearances can result in recirculation, a condition where air discharged from the cooling tower circles back around and reenters. On projects with multiple cooling towers, care must be taken to lay out each cooling tower in accordance with the manufacturer's stated requirements. Failure to do so could result in capacity falling short of scheduled values, which would be the fault of the design professional or contractor, not the cooling tower manufacturer.

MATERIALS OF CONSTRUCTION

Proper selection of cooling tower materials is important to the equipment's longevity. The corrosive nature of the air and water is of primary concern. Galvanized steel is commonly used in cooling tower construction. A step up is stainless steel, however a cooling tower constructed entirely of stainless steel can be significantly more costly than a galvanized steel tower. A good compromise is a hybrid approach consisting of a galvanized steel cooling tower with a stainless steel basin.

Fiberglass-Reinforced Plastic (FRP) is another material used in cooling tower construction. Early attempts at using this material resulted in towers that experienced structural degradation from exposure to the sun. Modern cooling towers made of FRP are designed to survive the outdoor elements and can be lower cost alternatives compared to steel construction. Field erected towers may be constructed of concrete, masonry, or wood.

CONDENSER WATER PIPING

Piping is another important factor to consider when designing a cooling tower system. Since cooling towers are almost always installed outdoors, it follows that at least part of the condenser water piping will be exposed to the outdoor elements. That means the condenser water piping may experience the sun's ultraviolet rays and freezing temperatures.

Exposure to UV light can degrade PVC pipe and decrease its impact resistance. Ambient temperatures below 32° F can freeze standing water in pipes which can cause bursting. A mechanical design professional may convince themselves that a particular cooling tower application will never operate in the winter, but it could prove unwise to rely on maintenance personnel to drain it once a year in order to protect it from freezing. Another strategy might be to have the control system continuously circulate water during freezing weather, but that would waste energy. The best way to protect outdoor pipes from freezing is to specify electrical heat tracing. Piping that is heat traced must be insulated. If the piping is insulated then there's no concern about UV light degradation for PVC piping. But many people get nervous about heat tracing PVC pipe. PVC pipe is only rated to 140° F.

The safest choice for condenser water piping is black steel. It can be specified with mechanical joints to bring the cost more in line with PVC. The cooling tower drain piping can also be black steel. Drain piping should be full size of the cooling tower drain connection so that it does not impede flow when the tower must be drained for maintenance purposes. The makeup water line can be copper, galvanized steel, or stainless steel, but it too should be heat traced and insulated.

SYSTEM CONSIDERATIONS

The typical cooling tower in an HVAC application is an open system, meaning there is a break in the piping system. The break occurs at the cooling tower. Open systems require special considerations, not the least of which is the fact that the water can escape. Consider the system depicted in Figure 14.

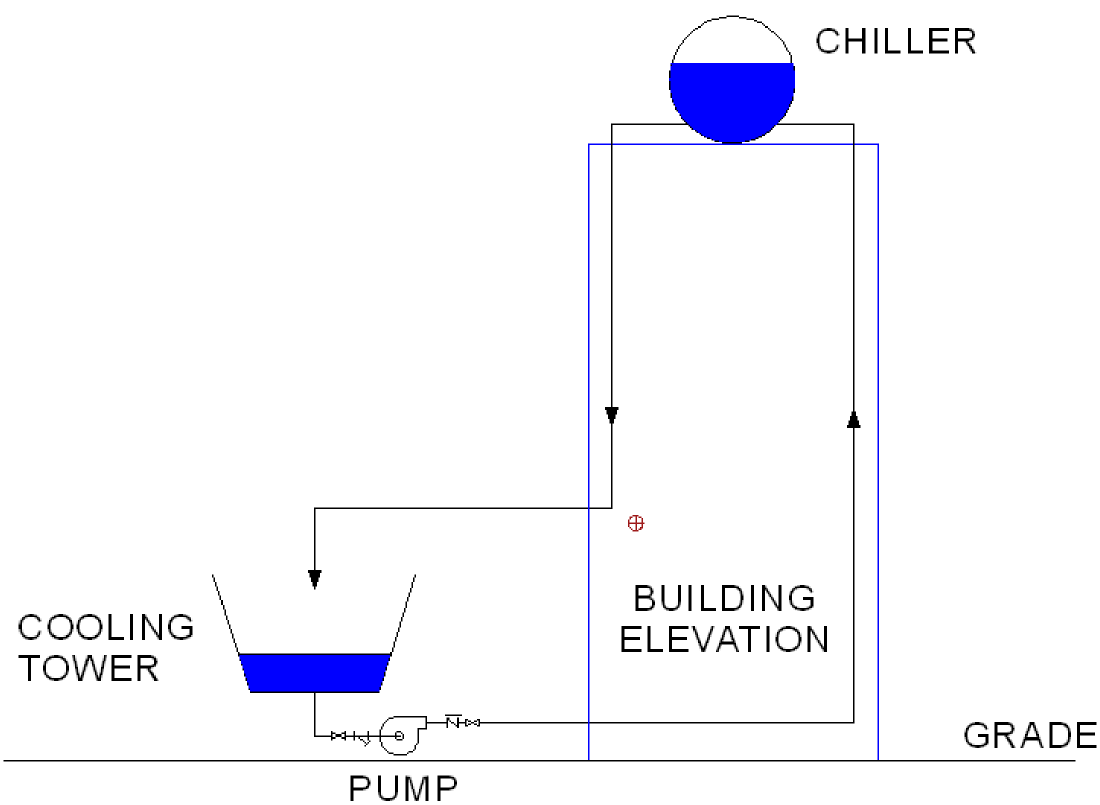

Figure 14: Condenser Water System

Figure 14 depicts a condenser water system for a multistory building. It consists of a cooling tower and a condenser water pump located at grade and a chiller located on the roof. For the purpose of this illustration, let's assume there are 10 water chillers on the roof and there's a vacuum breaker (not shown) at the highest point in the system.

The blue solid areas represent large volumes of water. There's condenser water in the cooling tower basin and more condenser water in the chiller barrels. It's difficult to see, but as in the larger scale drawings there is a strainer on the suction side of the pump and a check valve on the discharge side. The pump discharge piping supplies cool condenser water to the chillers, and hot condenser water is returned back to the cooling tower. So what is wrong with this picture? What will happen when the pump shuts down?

Even with BIM and three dimensional CAD, as design professionals we often think and work in two dimensions. Sometimes it's helpful to turn things on their side and look at them from a different perspective. In elevation view as shown in the diagram, we see that there's no issue on the discharge side of the pump. When the pump de-energizes, the check valve in the condenser water supply piping will close and the water in the condenser water supply piping will remain in place. However, on the other side of the chiller it's a different story. All of the water in the chillers and return piping will drain down into the cooling tower basin. The basin will overflow resulting in a mess of wasted water and treatment chemicals. The next time the pump starts up, there will be no return water available until the chillers fill back up. As a result, water will be pumped out of the basin faster than the makeup line can refill it and the pump will begin to cavitate.

So what to do? Put a check valve in the condenser water return piping? No, we want water to flow into the cooling tower, just not after the pump shuts down. Should we put a motorized valve in the condenser water return piping and interlock it with the pump? That would work, but it's not in keeping with the "KISS" principle (keep it simple stupid).

Refer to Figure 15 for a better solution. The small portion of pipe that rises above the highest water level in the system is referred to as a water trap. The water trap serves to prevent water in the chillers from draining back into the cooling tower and causing a host of related issues. In this case, the cooling tower basin would need to be oversized to accommodate the volume of water in the return piping due to the vacuum breaker being located at the highest point in the system. In other words, when the pump shuts down, all of the water in the return piping will drain into the cooling tower basin but the water in the chillers will not.

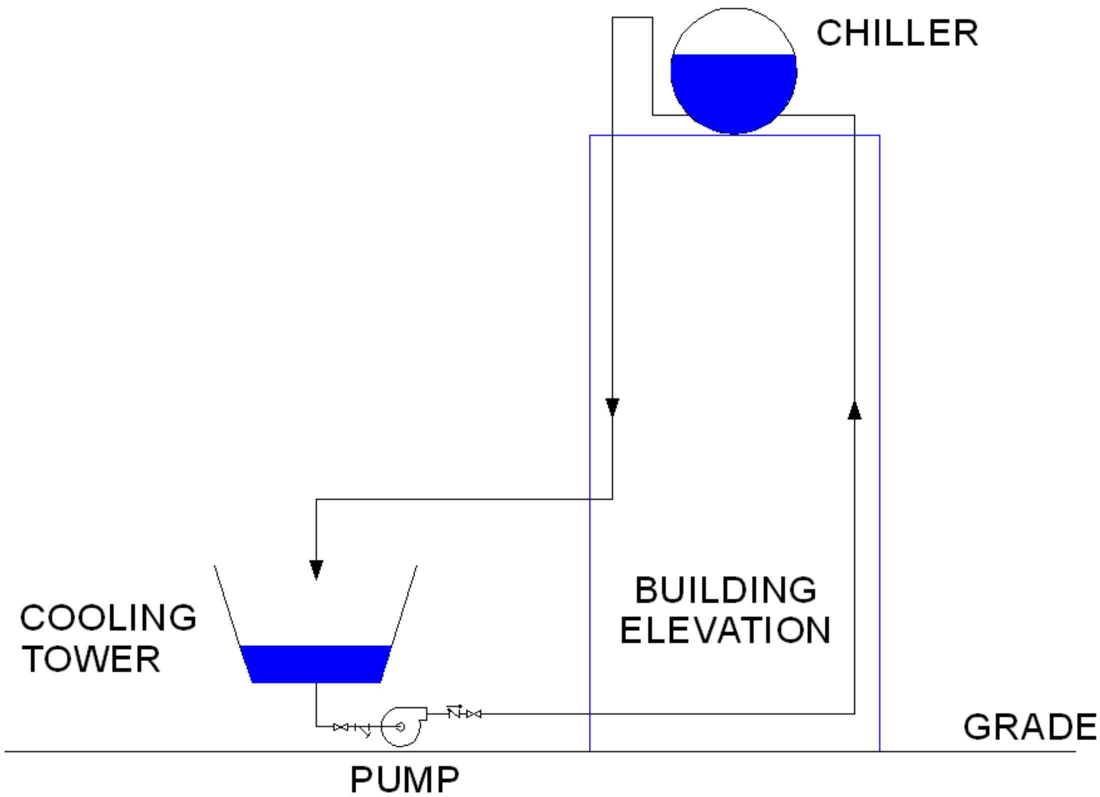

Figure 15: Condenser Water System – Problem Solved

Open systems like this present unique challenges with regard to pump sizing. An open system cannot be pressurized with an expansion tank like a closed system. That means we have to pay special attention to net positive suction head. The cooling tower should be elevated and the pump located beneath the cooling tower to provide adequate net positive suction head. Refer to Figure 16 for an example of an installation where the cooling towers are located above the condenser water pumps.

It is important to make the run of piping from the cooling tower basin to the pump inlet as short and as free of restrictions as possible. Pump sizing should include any changes in elevation, pipe friction loss, chiller pressure loss, and residual head required at the cooling tower inlet.

Figure 16: Elevated Cooling Towers with Condenser Water Pump located Beneath

Cooling tower drain piping must be provided. Due to the chemicals used, most locales do not allow discharge from cooling towers to be piped to the storm sewer. Check with local code authorities to determine if it is permissible for cooling tower waste to be discharged into the sanitary sewer system. If this is permissible, the cooling tower drain piping can discharge indirectly into a hub drain located beneath the cooling tower to protect it from rain.

WATER TREATMENT

In 1976, a mysterious illness broke out at an American Legion convention in Philadelphia. Symptoms included high fever, shortness of breath, coughing, headaches, muscle aches, nausea, and vomiting. 130 people were hospitalized and 25 died due to the illness. The CDC launched an investigation and traced the source back to contaminated water in the hotel's cooling tower. The illness was a form of atypical pneumonia, which we know today as Legionnaires' Disease.

This points to the importance of water treatment in a cooling tower system. The mechanical design professional should identify a designated area on the plans for chemical treatment equipment and include a detailed water treatment system description and scope of work in the construction specifications. Companies that specialize in chemical treatment for boilers and cooling towers will bid on the project and the winner will provide the system. The water treatment company will typically stay on as a continuing service provider to the owner.

Cooling tower water treatment systems consists of various chemicals that are pumped into the tower in order to control different issues. A common installation includes a series of electric metering pumps that sit atop chemical storage containers. This equipment should be located in a mechanical space such as where a chiller or self-contained unit is housed. The chemical treatment system needs shelter from the weather, electricity for the metering pumps, reasonable access to truck parking to replace empty chemical containers, and access to the condenser water piping. The metering pumps inject small quantities of chemicals into the system on a regular basis as prescribed by the water treatment provider.

The amount of minerals in the water supply, often referred to as hardness, varies by project locale. Due to the fact that water evaporates in the cooling tower, the water leaves behind mineral deposits referred to as *scale*. Scaling can be controlled by phosphoric acid. Acid and phosphates are used to control the water's pH, algae is controlled by chlorine, corrosion is treated with bicarbonates, and Legionella and other biologicals are treated with bromine. A natural alternative to some forms of chemical treatment is ozone.

COOLING TOWER WATER CONSUMPTION

As mentioned, some of the water circulating through a cooling tower evaporates as part of the cooling process. More water escapes the tower at the air exit in the form of mist which is known as *drift*. Still more water is purposely wasted to drain, a process called *blowdown*. The purpose of blowdown is to prevent the buildup of contaminants and scale. All of this water must be replaced with fresh makeup water.

When designing a mechanical system that includes a cooling tower, part of the mechanical design professional's responsibility is to size the makeup water line. In order to do that, one must first determine the peak makeup water requirement. The sum total of the makeup water required for evaporation + blowdown + drift can be approximated by 1.0 – 1.5% of the condenser water flow, or 30 – 45 GPM per 1,000 tons.

COOLING TOWER FILTRATION

Not only are cooling towers air-to-water heat exchangers, they are also very efficient air washers. Air leaving a cooling tower comes out much cleaner than when it went in. Although one could argue that clean air is a virtue, as mechanical design professionals we are more concerned about how dirty the water gets.

In the early days of cooling towers, water filters were sized for the full condenser water flow. Then as time went on people realized that it might not be necessary to filter the entire condenser water flow. The same objective can be achieved by employing sidestream filtration. Sidestream filtration involves taking a small portion of the full condenser water flow and filtering it. The approach saves both first cost and energy.

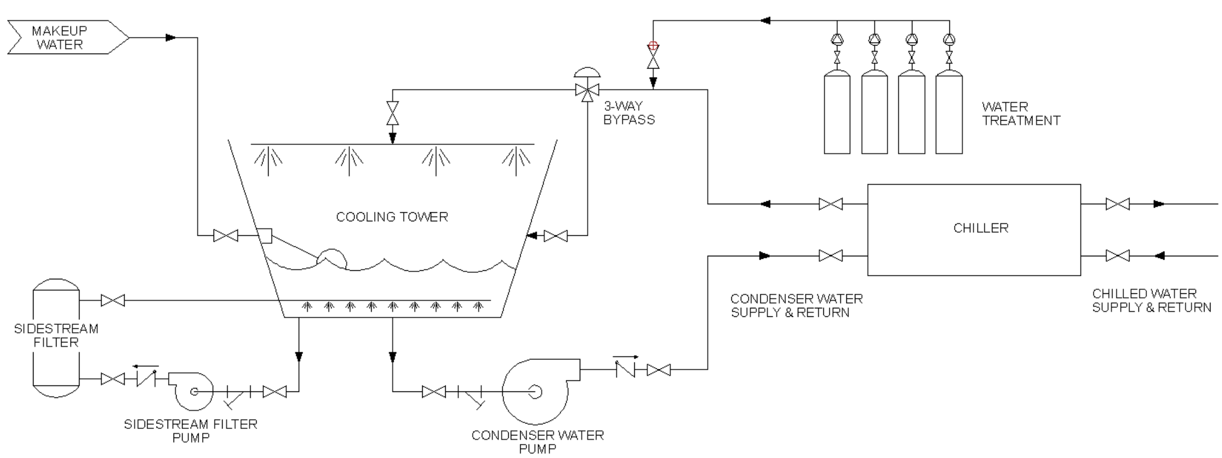

Figure 17: Cooling Tower with Sidestream Filtration and Water Treatment

Figure 17 depicts a cooling tower with sidestream filtration and water treatment. Sidestream filtration is typically sized at approximately 10% of full condenser water flow. The filtration can be accomplished by numerous methods including sand filters, centrifugal separators, and disc filters. A popular feature commonly used in conjunction with sidestream filtration is sweeper jets. Sweeper jets are nozzles that eject filtered water across the cooling tower basin floor at high velocity to stir up settled solids. Sweeper jets help prevent the buildup of solids, a condition that can lead to biological and corrosion issues.

ENERGY CODE

No discussion about cooling towers would be complete without mentioning the energy code. Most of the U.S. falls under the International Energy Conservation Code. The section in chapter 403 entitled *Heat Rejection Equipment* states that cooling towers with fan motors 5 horsepower and larger must have variable speed drives controlled by the cooling tower leaving water temperature.

CONCLUSION

In this final section, we will briefly touch on topics not yet covered in other sections, such as cells. A *cell* is the smallest independently functioning subdivision of a cooling tower. Typically, there is one fan per cell, so the easiest way to determine the number of cells is to count the number of fans, although this is not always the case. Manufacturers of alternative styles of cooling towers sometimes employ multiple fans per cell.

On all but the largest of projects, the design professional's decision regarding cooling tower cells will come down to a choice between one or two. The advantage of having two cells is that a failure in the other cell will still allow the cooling tower to function at 50% of its peak capacity. A cooling tower with only one cell that experiences a failure is dead in the water (no pun intended).

A *basin heater* is an electrical immersion heater designed to keep the water in a cooling tower basin from freezing. If the ASHRAE 99% winter design temperature for your project locale is 32° F or less, you should specify basin heaters. The cooling tower vendor representative can assist you with the required heater KW, or you can dust off your heat transfer book and do it yourself.

Depending on the manufacturer, cooling tower fans are available with direct drive, gear drive, and belt drive. Direct drive is usually reserved for alternative cooling tower designs. Most major cooling tower manufacturers provide a choice of gear or belt drive. The advantages of belt drive are the disadvantages of gear drive. Specifically, a gear drive is more expensive and more reliable, and a belt drive is less expensive and less reliable.

Maintenance on most cooling towers requires access to the upper surface. The section in chapter 306 of the International Mechanical Code entitled *Equipment and Appliances on Roofs and Elevated Structures* states that equipment requiring maintenance access that is 16 feet or more above grade must be provided with permanent ladders and catwalks with railings and guards. Cooling tower manufacturers can provide those for you, but you have to ask. It's always a good idea to include factory ladders and railings in the cooling tower specification. Figure 16 shows an installation with factory ladders and railings.

Drift eliminators, as the name implies, help eliminate drift. Drift eliminators consist of blades designed to change the trajectory of water droplets that get caught up in the airstream. Drift eliminators can limit drift losses to 0.002% of the condenser water flowrate.

Finally, some parting thoughts. As a design professional, your value to the organization is inversely proportional to your errors and omissions. The more frequent and costly your mistakes, the less valuable you are to the organization. Put another way, no matter how perfectly you execute hundreds of calculations and decisions made over the course of designing a project, you will be judged solely by the one mistake you make. That is why it is so important to be thorough. To check and recheck and re-double-check and confirm and verify and re-verify everything that you do. If only there were time to do that. In the words of the late great Leslie Nielson, good luck, we're all counting on you.

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