Cooling Tower Design

Typically, water cooled chillers reject heat from a process liquid loop that runs between the chiller and the cooling tower.

The process liquid loop is known as the condenser water loop in the building cooling industry. The condenser water is cooled by the cooling towers before being returned to the chillers at a lower temperature. A cooling tower is a heat rejection device that rejects waste heat to the atmosphere though the cooling of a water stream to a lower temperature.

The type of cooling that occurs in a cooling tower is termed "evaporative cooling". Evaporative cooling relies on the principle that flowing water, when in contact with moving air, will evaporate. In a cooling tower, only a small portion of the water that flows through the cooling tower will evaporate. The heat required for the evaporation of this water is given up by the main body of water as it flows through the cooling tower.

In other words, the vaporization of this small portion of water provides the cooling for the remaining un-evaporated water that is flowed through the cooling tower. The heat from the water stream transferred to the air stream raises the air's temperature and its relative humidity to 100%, and this air is discharged into the atmosphere. Figure 1 provides a simple schematic overview of a generic cooling tower flow diagram.

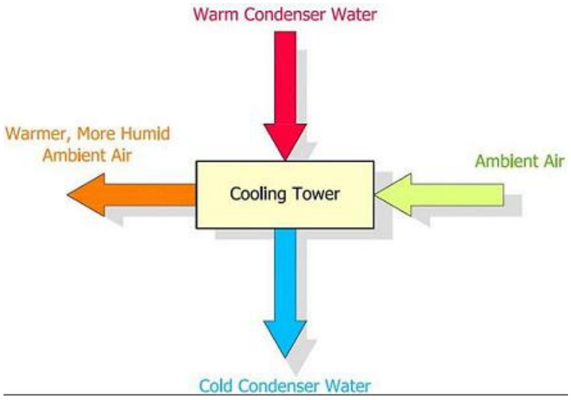

Figure 1: Schematic Overview of a Generic Cooling Tower Flow

Evaporative heat rejection devices, such as cooling towers, are commonly used to provide significantly lower water temperatures than are achievable with "air cooled" or "dry" heat rejection devices. “Air cooled” or “dry” heat transfer processes rely strictly on the “sensible” transfer of heat from the fluid to the cooling air across some type of system barrier and do not depend on the evaporation of water for cooling. Generally, in “air cooled” or “dry” heat transfer processes, the fluid is separated from the cooling air by a system barrier and it is not in direct contact with the cooling air.
A radiator in a car is a good example of this type of system and heat transfer process. “Sensible” cooling is limited by the temperature of the air flowing across the system barrier; the temperature of the fluid can never be cooled to a temperature that is less than the temperature of the air flowing across the system barrier. Evaporative cooling, on the other hand, can cool the fluid to a temperature less than the temperature of the air flowing through the cooling tower, thereby achieving more cost-effective and energy efficient operation of systems in need of cooling.

Common applications for cooling towers are to provide cooled water for air-conditioning, manufacturing and electric power generation. The smallest cooling towers are designed to handle water streams of only a few gallons of water per minute supplied in small pipes, while the largest cool hundreds of thousands of gallons per minute supplied in pipes as much as 15 feet (about 5 meters) in diameter on a large power plant.

Cooling towers come in a variety of shapes, sizes, configurations and cooling capacities. For a given capacity, it is common to install multiple smaller cooling tower modules (referred to as cells) rather than one, single, large cooling tower.

Since cooling towers require an ambient air flow path in and out, they are located outside, typically on a roof or elevated platform. The relative elevation of the cooling tower with the remainder of the cooling system needs to be considered when designing the plant because the cooling tower operation and connectivity relies on the flow of fluid by gravity.

Classification

The generic term "cooling tower" is used to describe both open circuit (direct contact) and closed circuit (indirect contact) heat rejection equipment. While most think of a "cooling tower" as an open, direct contact heat rejection device, the indirect cooling tower, is sometimes referred to as a "closed circuit fluid cooler" an is, nonetheless, also a cooling tower.

Figure 2: Direct Cooling Towers on an Elevated Platform

A direct or open circuit cooling tower (Figure 2) is an enclosed structure with internal means to distribute the warm water fed to it over a labyrinth of packing or "fill". The fill may consist of multiple, mainly vertical, wetted surfaces upon which a thin film of water spreads (film fill) or several levels of horizontal splash elements that create a cascade of many small water spreads (splash fill). The purpose of the “fill” is to provide a vastly expanded air-water interface for the evaporation process to take place. The water is cooled as it descends through the fill by gravity while in direct contact with air that passes over it.

The cooled water is then collected in a cold water basin or sump that is located below the fill. It is then pumped back through the process equipment to absorb more heat. The moisture laden air leaving the fill is discharged to the atmosphere at a point remote enough from the air inlets to prevent its being drawn back into the cooling tower (Figure 3).

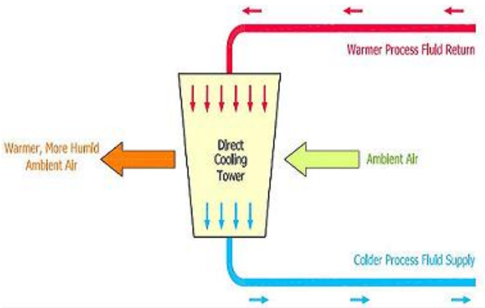

Figure 3: Direct or Open Circuit Cooling Tower Schematic Flow Diagram

An indirect or closed circuit cooling tower involves no direct contact of the air and the fluid being cooled. A type of heat exchanger defines the boundaries of the closed circuit and separates the cooling air and the process fluid. The process fluid being cooled is contained in a "closed" circuit and is not directly exposed to the atmosphere or the recirculated external water. The process fluid that flows through the closed circuit can be water, a glycol mixture or a refrigerant.

Unlike the open circuit cooling tower, the indirect cooling tower has two separate fluids flowing through it; one is the process fluid that flows through the heat exchanger and is being cooled while the other is the cooling water that is evaporated as it flows over the “other” side of the heat exchanger. Again, system cooling is provided by a portion of the cooling water being evaporated as a result of air flowing over the entire volume of cooling water.

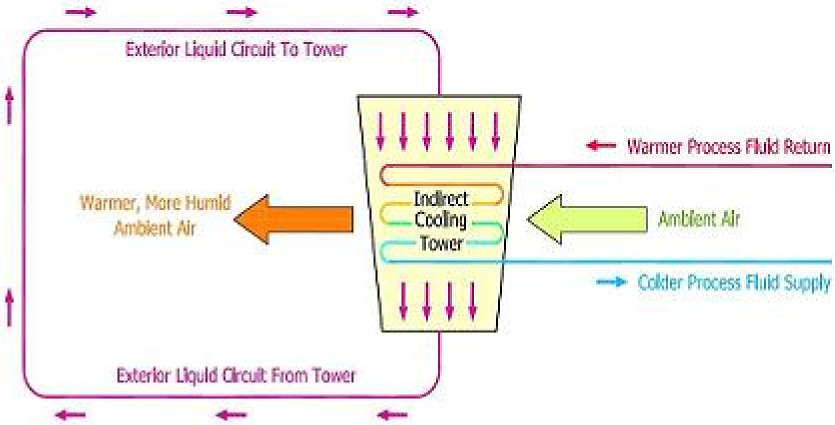

Figure 4: Indirect Cooling Tower Schematic Flow Diagram

In addition to direct and indirect, another method to characterize cooling towers is by the direction the ambient air is drawn through them. In a "counter-flow" cooling tower, air travels upward through the fill or tube bundles, directly opposite to the downward motion of the water. In a cross-flow cooling tower, air moves horizontally through the fill as the water moves downward.

Cooling towers are also characterized by the means with which air is moved. Mechanical-draft cooling towers rely on power-driven fans to draw or force the air through the tower. Natural-draft cooling towers use the buoyancy of the exhaust air rising in a tall chimney to provide the air flow. A fan-assisted natural-draft cooling tower employs mechanical draft to augment the buoyancy effect. Many early cooling towers relied only on prevailing wind to generate the draft of air.

Make-Up Water

For the recirculated water that is used by the cooling tower, some water must be added to replace, or make-up, the portion of the flow that evaporates. Because only pure water will evaporate as a result of the cooling process, the concentration of dissolved minerals and other solids in the remaining circulating water that does not evaporate will tend to increase. This build up of impurities in the cooling water can be controlled by dilution (blow down) or filtration.

Some water is also lost by droplets being carried out with the exhaust air (a phenomenon known as drift or carry-over), but this is typically reduced to a very small amount in modern cooling towers by the installation of baffle-like devices, appropriately called drift eliminators, to collect and consolidate the droplets.

To maintain a steady water level in the cooling tower sump, the amount of make-up water required by the system must equal the total of the evaporation, blow-down, drift and other water losses, such as wind blowout and leakage.

Reference:

http://www.datacenterjournal.com/News/Article.asp?article_id=267