Cooling Towers

An Online Continuing Education Course for Engineers

Course Number: M-7002

Credit: 7 Hours / 7 PDH / 7 CPD

Cooling Towers

Introduction

Most industrial production processes need cooling water to operate efficiently and safely. Refineries, steel mills, petrochemical manufacturing plants, electric utilities and paper mills all rely heavily on equipment or processes that require efficient temperature control. Cooling water systems control these temperatures by transferring heat from hot process fluids into cooling water. As this happens, the cooling water itself gets hot; before it can be used again it must either be cooled or replaced by a fresh supply of cool water.

A Cooling Tower is a heat rejection device that extracts waste heat to the atmosphere by cooling a stream of hot water in the tower. This type of heat rejection is termed "evaporative" because it allows a small portion of the water being cooled to evaporate into a moving air stream and thereby provides significant cooling to the rest of that water stream. The heat that is transferred from the water stream to the air stream raises the air's temperature and its relative humidity to 100%, and this air is discharged to the atmosphere.

Types of Cooling Processes

Two basic types of water cooling processes are commonly used. One transfers the heat from warmer water to cooler air mainly by an evaporation heat-transfer process and is known as the evaporative or wet cooling. These are also termed as open systems. The other transfers the heat from warmer water to cooler air by a sensible heat-transfer process and is known as the non-evaporative or dry cooling. These are also termed as closed cooling water systems because the water does not come in contact with outside air.

Dry cooling towers operate by heat transmission through a surface that divides the working fluid from ambient air. These rely mainly on convection heat transfer to reject heat from the working fluid, rather than evaporation. The cooling takes place through air-cooled exchangers similar to radiators.

The advantages of these systems include:

1. Precise temperature control, which is critical in many process applications

2. The water loss is negligible as the water remains in a closed loop. This system consumes very little water for make up and thus water treatment costs will be less. This system is recommended where water is scarce.

3. Ability to operate at very high temperatures (200ºF) and under sub-freezing conditions using ethylene glycol, alcohol or brines.

Another variant of a closed cooling system is the once through system. Here the cooling water is drawn from an estuary, lake or river; used in the process once and is disposed back to the source. There is no re-circulation.

Once-through cooling is usually employed when the cooling water demands are high and water is readily available in abundance. Environmental regulation of hot water discharge or concerns of aquatic life go against using this system. Local environment authorities having jurisdiction must permit such an installation.

An **evaporative system** is a recirculation water system that accomplishes cooling by providing intimate mixing of water and air, which results in cooling primarily by evaporation. A small portion of the water being cooled is allowed to evaporate into a moving air stream to provide significant cooling to the rest of that water stream.

Water is re-circulated and reused again and again. The water evaporation is approximately 1% of the flow for each 10ºF drop in temperature. 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 to the atmosphere.

In general, most applications rely on the use of evaporative cooling tower systems, which include wet cooling towers, cooling ponds or spray ponds.

The course covers 18 sections of comprehensive information on evaporative cooling towers and provides important aspects of cooling tower types, sizing, selection and performance issues. Let’s first define a few important terms for understanding this course. A detailed glossary is provided at the end of the course.

Cooling Tower Terms and Definitions

Some useful terms, commonly used in the cooling tower industry:

1. **BTU (British thermal unit) -** BTU is the heat energy required to raise the temperature of one pound of water one degree Fahrenheit in the range from 32° F to 212° F.

2. **Cooling Range** - The difference in temperature between the hot water entering the tower and the cold water leaving the tower is the cooling range.
3. **Approach** - The difference between the temperature of the cold water leaving the tower and the wet- bulb temperature of the air is known as the approach. Establishment of the approach fixes the operating temperature of the tower and is a most important parameter in determining both tower size and cost.
4. **Drift** - Water droplets that are carried out of the cooling tower with the exhaust air. Drift loss does not include water lost by evaporation. Proper tower design can minimize drift loss. The drift rate is typically reduced by employing baffle-like devices, called drift eliminators, through which the air must travel after leaving the fill and spray zones of the tower.
5. **Heat Load** - The amount of heat to be removed from the circulating water within the tower. Heat load is equal to water circulation rate (gpm) times the cooling range times 500 and is expressed in BTU/hr. Heat load is also an important parameter in determining tower size and cost.
6. **Ton** - An evaporative cooling ton is 15,000 BTU's per hour. The refrigeration ton is 12000 BTU’s per hour.
7. **Wet Bulb Temperature (WBT)** - The lowest temperature that water theoretically can reach by evaporation. Wet-Bulb temperature is an extremely important parameter in tower selection and design and should be measured by a psychrometer.
8. **Dry-Bulb Temperature** - The temperature of the entering or ambient air adjacent to the cooling tower as measured with a dry-bulb thermometer.
9. **Pumping Head** - The pressure required to pump the water from the tower basin, through the entire system and return to the top of the tower
10. **Makeup** - The amount of water required to replace normal losses caused by bleed off, drift, and evaporation.
11. **Bleed off** - The portion of the circulating water flow that is removed in order to maintain the amount of dissolved solids and other impurities at an acceptable level. As a result of evaporation, dissolved solids concentration will continually increase unless reduced by bleed off

Section 1 – Evaporative Cooling Towers

An evaporative cooling tower is a heat exchanger that transfers heat from circulating water to the atmosphere. Warm water from the heat source is pumped to the top of the tower and will then flow down through plastic or wooden shells. As it falls downward across baffles, the water is broken into small droplets. Simultaneously, air is drawn in through the air inlet louvers at the base of the tower and travels upward through the wet deck fill opposite the water flow. A small portion of the water is evaporated which removes the heat from the remaining water causing it to cool down 10 to 20˚C. The water falls down into a basin and will be brought back into the production process from there. Some of the water is lost to evaporation and thus the fresh water is constantly added to the cooling tower basin to make up the difference.

Cooling Tower Principle

Evaporation results in cooling…

On a warm day when you work or play hard, your body heats up, and you begin to sweat. Because your skin is more moist than the air, the sweat EVAPORATES and it ABSORBS heat from your body. By absorbing heat from your body, the temperature of your body is lowered. It is the evaporation or the change from a liquid to a vapor of the water on your skin which causes the skin to be cooled. If you stand in a breeze, you feel cooler, even though the temperature of the breeze will be the same as the temperature of still air. The breeze STEPS UP the EVAPORATION process of the sweat and more rapidly cools the body. It is not the breeze alone that makes you feel cooler. It is the increase in the rate of evaporation which makes the body feels cooler.

All cooling towers operate on the principle of removing heat from water by evaporating a small portion of the water that is recirculated through the unit. The heat that is removed is called the latent heat of vaporization. Each one pound of water that is evaporated removes approximately 1,050 BTU's in the form of latent heat. The amount of heat lost by the water depends on the temperature rise of the ambient air before it leaves the tower. This means that both the dry bulb and wet bulb temperatures of the air are important. When WBT = DBT, this condition corresponds to 100% relative humidity (RH) that implies the air is fully saturated.

The air will no longer accept water and the lack of evaporation does not allow the wetted bulb to reject heat into the air by evaporation.

The higher the difference between DBT and WBT, the lower is the relative humidity, meaning that the air is drier. The lower relative humidity indicates greater capacity of air to absorb or hold water and shall result in efficient lowering of water temperatures.

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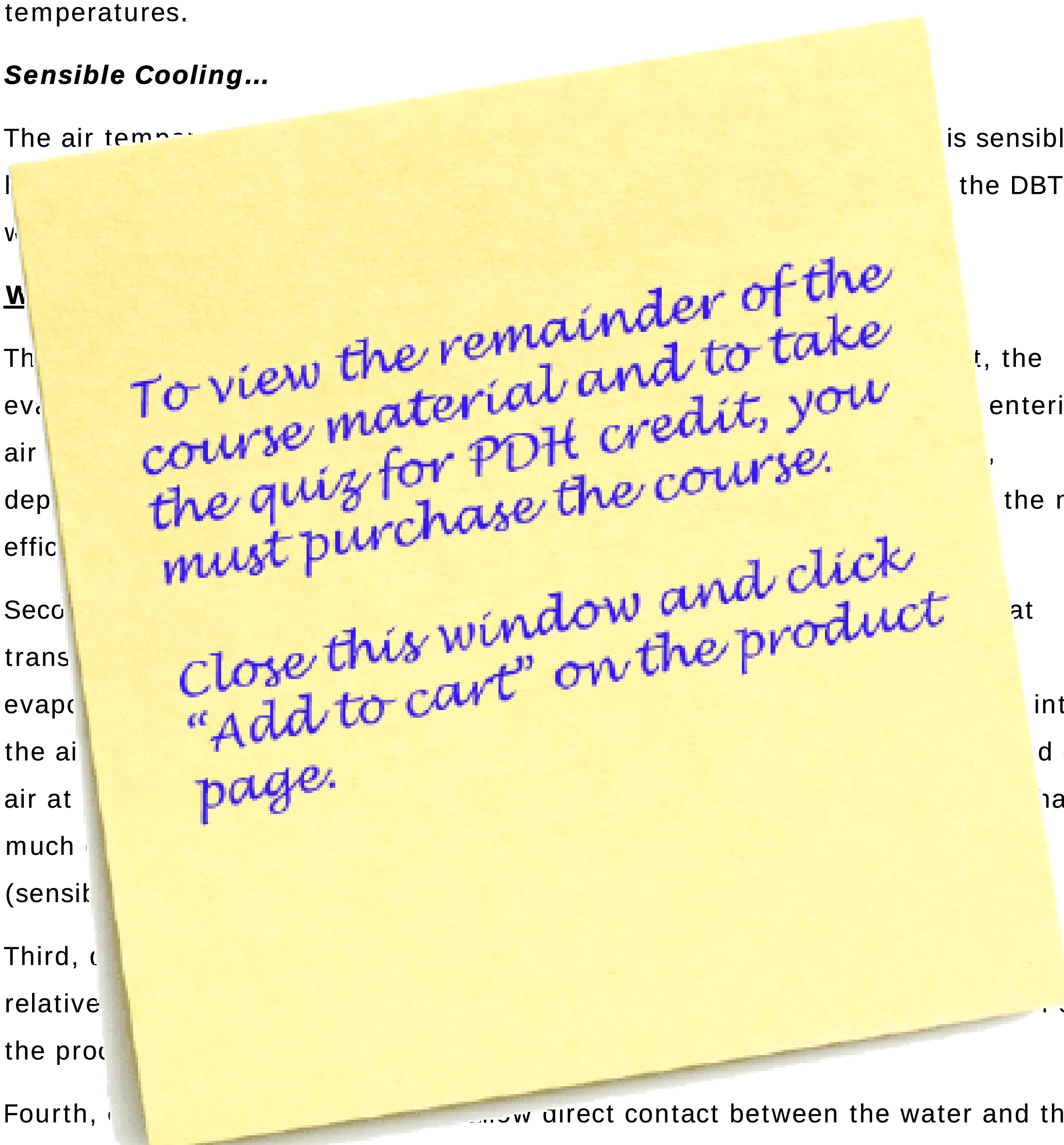

Fourth, … ow direct contact between the water and the air, which i… …ghly efficient process. This mixing occurs in the fill, sometimes called the wet deck, which is typically comprised of sheets of thermoformed plastic. The fill provides a large amount of low-cost surface area for air and water to contact each other.