SEMINAR ON COOLING TOWERS

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Contents for Discussion

Introduction

- **Industrial processes produce excess heat usually in form of hot water that must be cooled and reused. Cooling towers dissipate this heat quickly by circulating hot process water in presence of air to maximize evaporation.**

- **Industrial water prepared for discharge must also be cooled to preserve the delicate balance of nature.**

- **Cooling towers are designed to expose the largest surface area of transient water to maximum air flow, for the longest period of time.**

- **Process water is delivered to hot water inlets located at the top of the towers. It is allowed to flow down through the heat transfer media in the tower by either gravity (through a metering orifice) or by pressurized nozzles.**

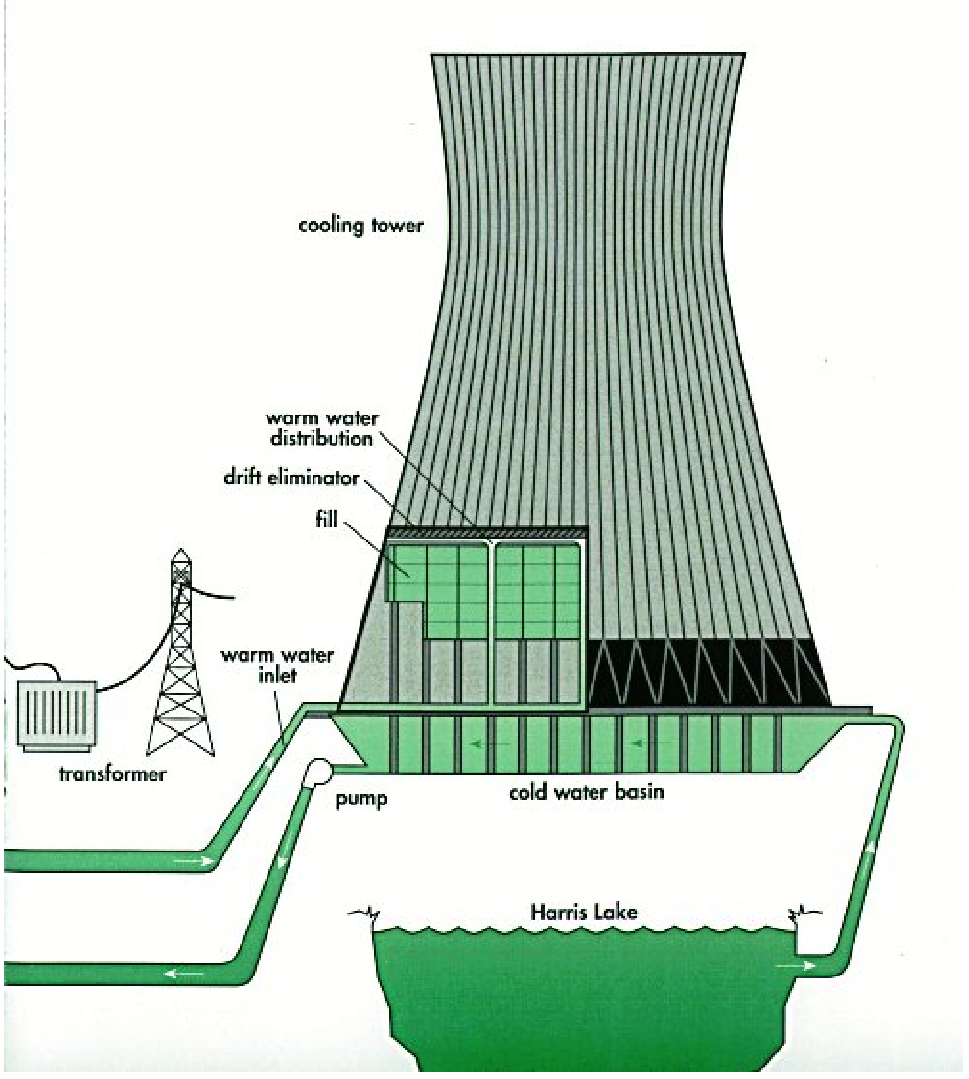
Tower Classifications

Cooling towers are broadly categorized by following considerations:

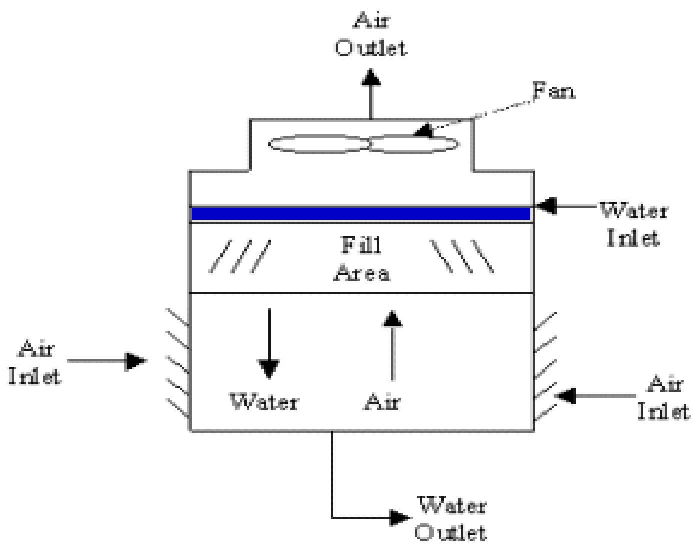
1. **Whether there is direct or indirect contact**
2. **The mechanism used to provide the required airflow**
3. **The relative flow paths of air and water**
4. **The primary materials of construction**
5. **The type of heat transfer media applied**
6. **The tower's physical shape**

Natural Draft Cooling Tower

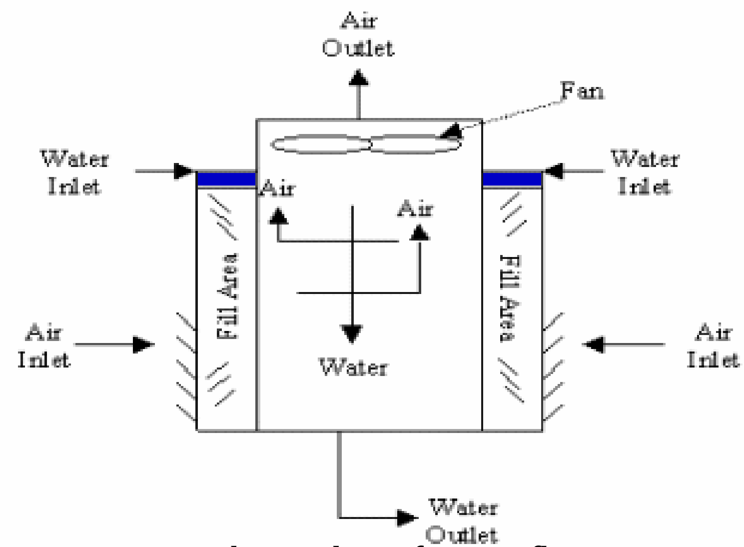
- **So named for their shape**
- **Provide extremely dependable and predictable thermal performances**
- **Air flow is produced by a density differential between the heated (less dense) air inside the tower and relatively cool (more dense) ambient air outside the tower**
- **Performance is favored in climates with high relative humidity**
- **Such towers, often as tall as 500 ft., are suitable for high process water throughput (to 600,000 gal/min)**
- **common in the field of electric power generation.**



Mechanical Draft Towers



Mechanical Draft Counterflow Tower



Mechanical Draft Crossflow Tower

- **These are favored in chemical and petroleum-refining industries**
- **They use one or more motor-driven fans to provide air flow through the tower**
- **In the *induced draft* configuration, fans are located in the exiting air stream at the top of the tower**
- **In the *forced draft* configurations fans are located at the bottom**
- **Counterflow towers are less open than crossflow towers, so the warm water moving through the tower is exposed to relatively little sunlight. This minimizes algae growth**
- **Counterflow towers have established a position as the lowest cost, most space-saving type and are the current design of choice under normal operating circumstances**
- **However maintenance personnel prefer crossflow towers, whose key components are open to view and easily accessible for servicing**

Tower Fills

Key Features of Film Fill

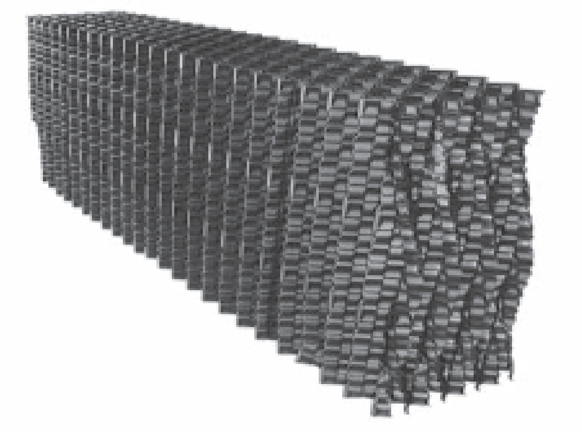
- **Greater cooling capacity in a given space**
- **Low-clog designs available**
- **Available in bottom supported or hanging designs**
- **Crossflow and counterflow designs**
- **Integral louvers and eliminators available in crossflow design.**
- **High-temperature designs available**
- **Single-piece, full-height counterflow designs available**

Key Features of Splash Fill

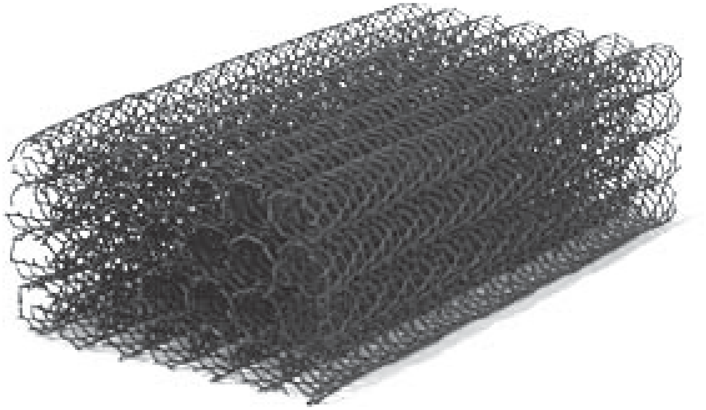
- **Ideal in "dirty water" applications**
- **Far more forgiving of poor water distribution caused by clogged or missing nozzles**
- **Water easily redistributes itself**
- **Ideal in dusty or wooded environments**
- **Easy maintenance**
- **Long service life**
- **High-temperature designs available**
- **Designs available for heavy ice loads**

Diagrams Of Some Tower Fills

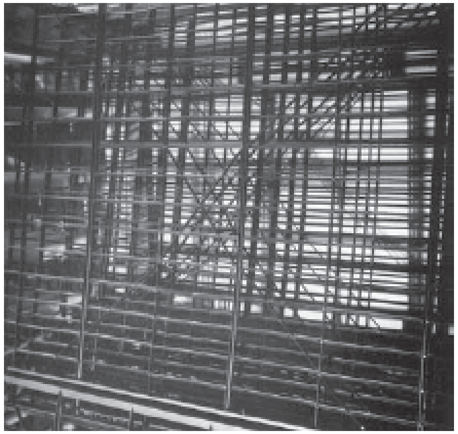
MX crossflow PVC film-fill with integral louvers and eliminators



DF254 low-clog counterflow PVC film-fill



TrickleBloc counterflow polypropylene splash-fill



Ladder crossflow polypropylene splash-fill

Materials Of Construction

Wood: Because of its availability, workability, relative low cost and durability under very severe operating conditions encountered in cooling towers, wood remains the predominant structural material

- wood suffers a reduction in structural characteristics in a prolonged wet environment under elevated temperatures
- wood must be treated with preservatives like Chromated copper arsenate (CCA) and acid copper chromate (ACC) to prevent fungal attack and retard decay

Plastics: It is widely used as the structural and component material due to its inherent resistance to microbiological attack, corrosion and erosion; its compatibility with other materials; formability; good strength to weight ratio; and acceptable cost level e.g. PVC,FRP, Polypropelene

Steel and stainless steel: Steel towers are growing in popularity due to their consistent structural strength, building and fire code requirements and environmental acceptability. Galvanized steel is a better choice.

Concrete: It has been used for many years to build hyperbolic cooling towers and this technology has also been applied in large mechanical draft towers. Currently concrete is considered as a viable alternative material on the smaller mid-range (25,000 to 100,000 gal/min) industrial towers. Its higher initial cost of concrete construction is justified by reduced fire risk and higher load-carrying capability.

Water Quality

<u>Water should have:</u>

1. pH between 6 to 8.5
2. Chloride content (as NaCl) should below 750 ppm.
3. sodium bicarbonate content below 200 ppm
4. sulfate content below 1,200 ppm
5. maximum temperature of 1200 F
6. Chlorine if used should be added intermittently as needed, so that the free residual chlorine does not exceed 1 ppm

<u>Controls to maintain desired water quality</u>:

<u>Blowdown</u>: A portion of recirculating water is continuously evacuated and replenished with relatively pure makeup water

Other methods are: *Scale prevention* , *Corrosion control* , *Biological growth reduction* , *Control of foreign materials*:

Cooling Tower Theory

- Heat is transferred from water drops to the surrounding air by the transfer of sensible and latent heat.
- This movement of heat can be modeled with a relation known as the **Merkel Equation**:

$$\frac{KaV}{L} = \int_{T_2}^{T_1} \frac{dT}{h_w - h_a}$$

where: KaV/L = tower characteristic

T1 = hot water temperature (0F or 0C)

T2 = cold water temperature (0F or 0C)

T = bulk water temperature (0F or 0C)

hw = enthalpy of air-water vapor mixture at bulk water temperature (J/kg dry air or Btu/lb dry air)

ha = enthalpy of air-water vapor mixture at wet bulb temperature (J/kg dry air or Btu/lb dry air)

C' = Entering air enthalpy at wet-bulb temperature, WBT

BC = Initial enthalpy driving force

CD = Air operating line with slope L/G

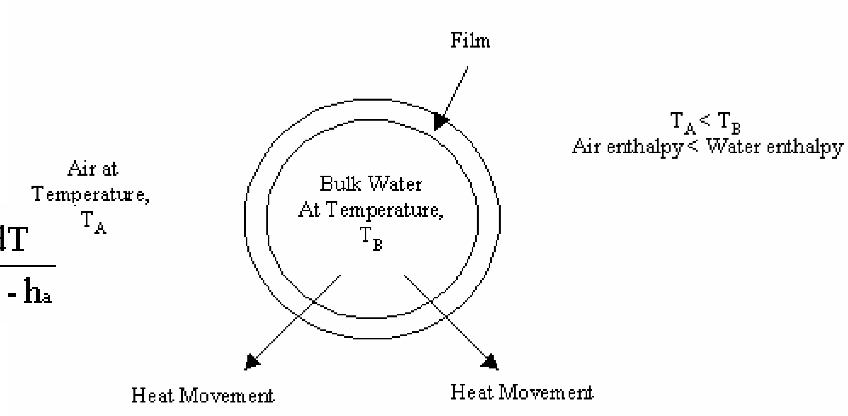
DEF = Projecting the exiting air point onto the water operating line and then onto the temperature axis shows the outlet air web-bulb temperature

From thermodynamics

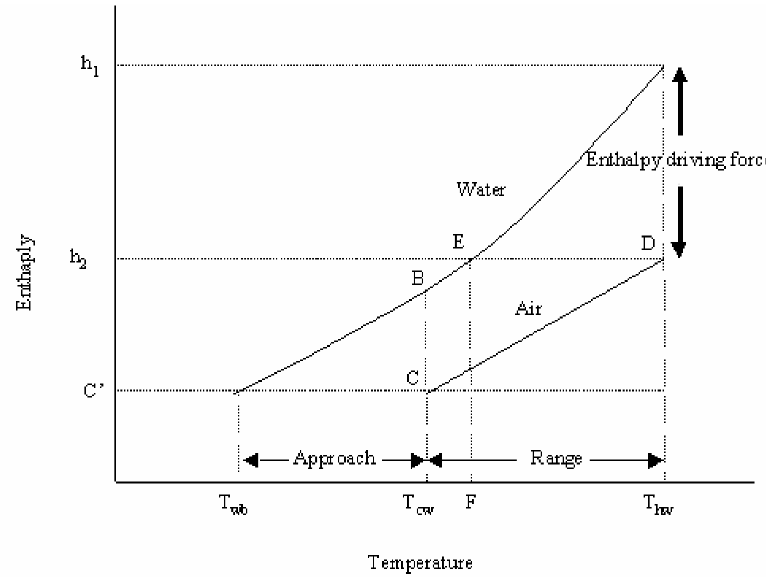
$$L(T_1 - T_2) = G(h_2 - h_1)$$

$$\frac{L}{G} = \frac{h_2 - h_1}{T_1 - T_2}$$

Where h1,h2 are enthalpy of air-water vapor mixture at Inlet and outlet WBTs

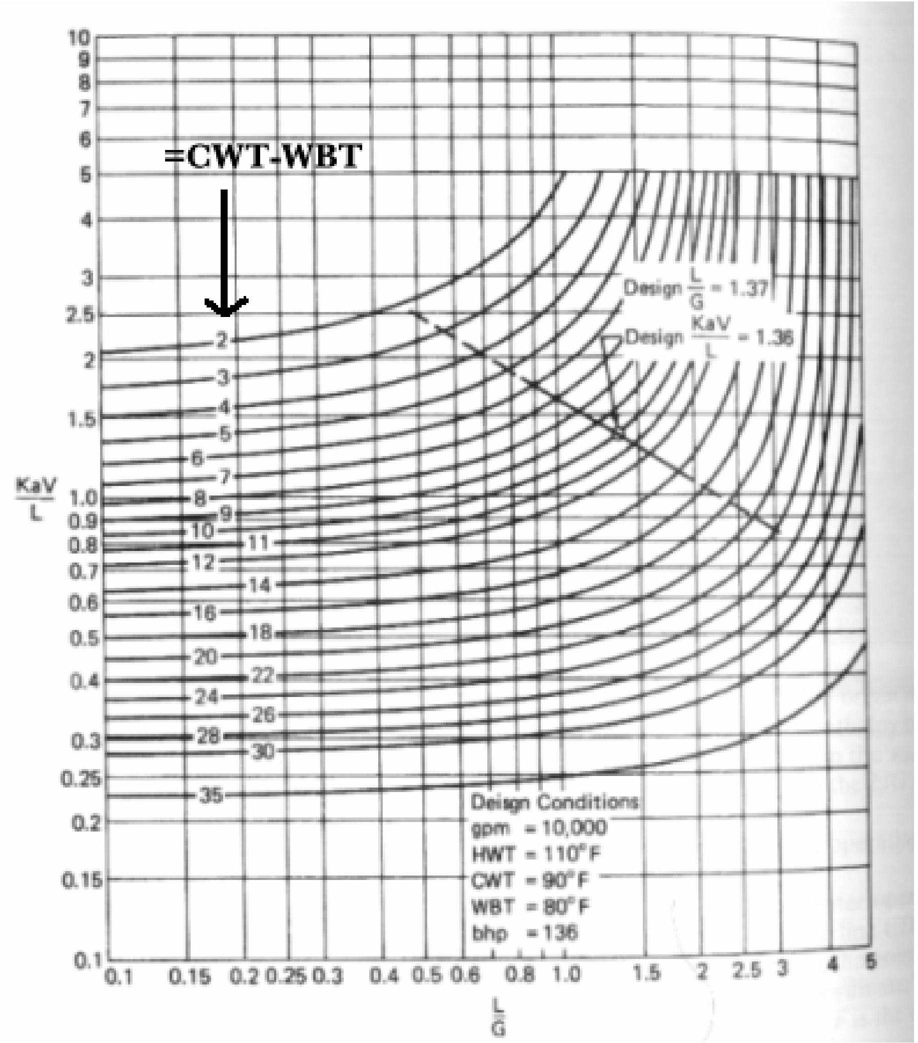


Water Drop with Interfacial Film

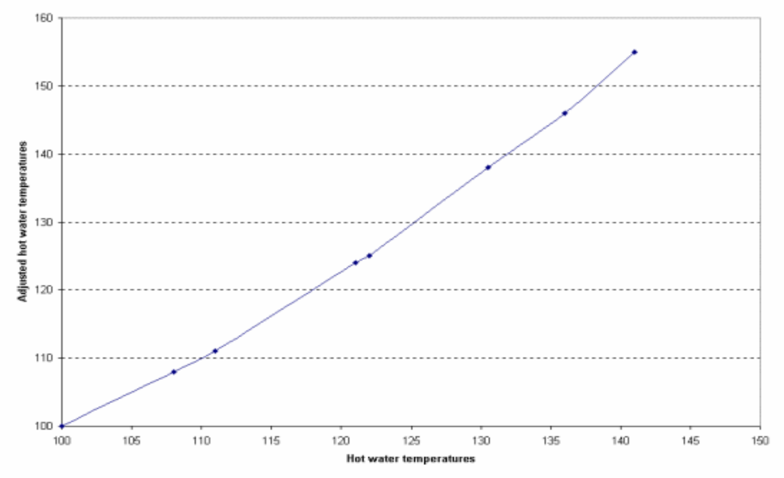


Graphical Representation of Tower Characteristic

Design Consideration



A Typical Set of Tower Characteristic Curves



Graph of Adjusted Hot Water Temperatures

- The increased heat load causes the hot water temperature to increase considerably faster than does the cold water temperature. Although the area ABCD should remain constant, it actually decreases about 2% for every 10 0F increase in hot water temperature above 100 0F. To account for this decrease, an "adjusted hot water temperature" is used in cooling tower design.
- Although KaV/L can be calculated, designers typically use charts found in the Cooling Tower Institute Blue Book to estimate KaV/L for given design conditions
- The straight line shown in above Figure is a plot of L/G vs KaV/L at a constant airflow. The slope of this line is dependent on the tower packing, but can often be assumed to be -0.60
- Cooling towers are designed according to the highest geographic wet bulb temperatures. This temperature will dictate the minimum performance available by the tower.

Conclusion

- ***A cooling tower*** **is a heat rejection device, which extracts waste heat to the atmosphere though the cooling of a water stream to a lower temperature. The type of heat rejection in a cooling tower is termed "evaporative" in that it allows a small portion of the water being cooled to evaporate into a moving air stream to provide significant cooling to the rest of that water stream.**
- ***Cooling towers*** **are a very important part of many chemical plants. They represent a relatively inexpensive and dependable means of removing low grade heat from cooling water.**
- ***Natural draft designs*** **use very large concrete chimneys to introduce air through the media. Due to the tremendous size of these towers (500 ft high and 400 ft in diameter at the base) they are generally used for water flowrates above 200,000 gal/min. Usually these types of towers are only used by utility power stations in the United States**
- ***Mechanical draft cooling towers*** **are much more widely used. These towers utilize large fans to force air through circulated water.   The water falls downward over fill surfaces which help increase the contact time between the water and the air. This helps maxim**

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