Design of Passive down Draft Cool Tower for 100 m^2 Auditorium

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***Abstract*—*A passive down draft evaporative cooling (PDEC) tower is design to capture the wind at high temperature typically at 40^o C and above the top of tower and cool the outdoor air using water which is allowed to flow through shower and due to evaporation of water out door air gets cooled. Many different types of PDEC exist. This paper explains design of PDEC tower. It is a parallel flow heat exchanger with hot and cold fluid are in direct contact with each other. The wet bulb temperature of air is the lowest possible temperature of the air leaving the tower and entering in air conditioned space. It is suitable in hot dry climate due to large difference between dry and wet bulb temperatures. The mathematical model predicted with the variation of wind speed from 1 m/s to 6 m/s with outside air temperature 35 ^{o} C and relative humidity 20 %, a tower height of 6 m is required.*

Keywords*—*LMTD, Parallel flow heat exchanger, Evaporative cooling.

I. INTRODUCTION

A simple type of PDEC (passive downdraught evaporative cooler) technology, wind towers, has been widely used since ancient Egypt. These components have been advanced in order to improve the cooling performance of traditional wind towers by installing evaporative cooling devices such as pads or sprays (Baradhori, 1985; Cunningham and Thompson, 1985.) Different studies have investigated these advanced types of PDEC technology and shown that they accomplish better cooling performance and response to the cooling demands in a space than wind towers. Due to the complexity of the physical processes, studies have focused on field measurements and computational analysis as there are not any available exact analytical solutions to solve the complex phenomena involved.

II. EVAPORATIVE COOLING

According to the Evaporative Air Conditioning Handbook (Watt and Brown, 1997), simultaneous heat and mass transfer occurs between substances when the temperatures and vapor pressures are different in direct evaporative cooling. In the case of mixtures of air and water, which is the most common evaporative cooling process, these phenomena occur when the gaseous phase of water, i.e., water vapor, and non-saturated air come in contact with each other at a thermally isolated boundary. Heat is transferred from the warmer to the cooler substance. Mass is transferred from the higher to the lower water vapor pressure by evaporation near the water surface, mixing the water vapor into the air. The temperatures and vapor pressures reach equilibrium since heat equalizes the temperatures, and evaporation increases or decreases the vapor pressures in each substance. These phenomena, simultaneous heat and mass transfer, take place until temperatures and vapor pressures are equalized. The cooling efficiency of direct evaporative cooling components thus becomes 100% when the air is saturated at the equilibrium temperature in the adiabatic cooling processes.

Both sensible and latent heat transfer is involved in a direct evaporative cooling process. Sensible heat affects only the temperature while latent heat only affects the moisture level of the mixture. In the case of a mixture of air and water, sensible heat flow raises or lowers the temperatures of both, and latent heat transfers water vapor into the air by evaporation, so that both the temperature and moisture content of the air-water mixture are altered. If no external heat is involved in the processes, the sensible heat of the air is delivered to the water and the amount of sensible heat becomes latent heat by evaporating the water. This net heat conversion from sensible heat to latent heat is adiabatic saturation, and it governs almost all direct evaporative air cooling processes.

The water, however, gains some external sensible heat while being re-circulated or mixed with makeup water which is typically at a different temperature than the air. Adiabatic saturation is thus only a close approximation of most direct evaporative cooling cases. The ideal direct evaporative cooling process takes place when the water temperature and the wet bulb temperature of the air are both the same, and no heat addition or loss occurs during the process.

The air temperature in the ideal direct evaporative cooling thus varies along a line of constant enthalpy on the psychrometric chart, while the most typical direct evaporative cooling processes follow the dashed line, where the temperature of the mixture is slightly higher than that experienced in an ideal adiabatic cooling process as shown in Figure 1 . Figure shows theoretical heat transfer process on enthalpy chart. .

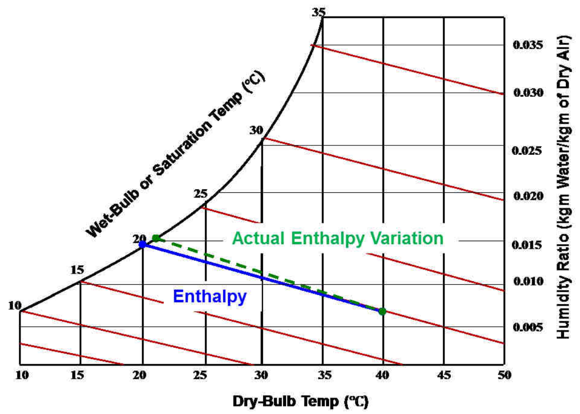

Fig.1: Enthalpy variation of the evaporative cooling

Evaporative cooling can be generally divided into two different types: direct and indirect. Direct evaporative cooling is a simple, established, and popular cooling technology. In this type of evaporative cooling, both fluids are in direct contact with each other during the evaporative cooling processes.

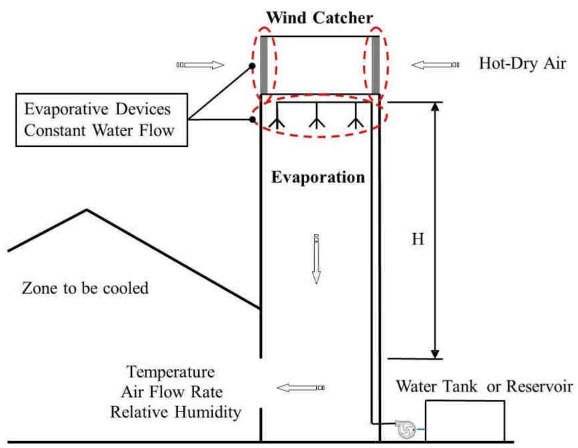

Fig.2: Schematic diagram of typical wind tower

The water evaporates and humidifies the air, causing a decrease in temperature and an increase in humidity. The wet bulb temperature of the air is the lowest possible temperature of the air leaving the evaporative cooling system. It is thus suitable in hot dry climates due to the large differences between the dry- and wet-bulb temperatures. Applications of this type of cooling system include evaporative coolers, air washers, and humidifiers.

Figure 2 show from top of tower air is allowed to enter inside the tower. Filters are also mounted on the top of the tower. The purpose of filter is to collect dust from the air. Showers are placed on the top of tower. From shower continuous water is sprayed in the tower. Cold water and hot air comes in contact with each other. Heat transfer takes place, decreeing the moist air temperature. The water is collected at the bottom; the same water is pumped again at the top of tower. The cold moist air is circulated to the designed air conditioned space.

III. EVAPORATION OF A WATER DROPLET

The steady-flow surface energy balances in the process of simultaneous heat and mass transfer within the control volume in can be written as

$\dot{m}$ □□h □ □$\dot{Q}$ (1)

For parallel flow heat exchanger heat lost by hot air and gained by evaporation of water.

$$Q = ma \times Cp \times \Delta T = mw \times hfg = U \times A \times LMTD \quad (2)$$

Where

Q = Heat transfer, kW

ma = Mass flow rate of air , kg/s

Cp = Specific heat of moist air, kJ/kg ^{o}C

ΔT= Temperature difference between hot air inlet and cold air inlet to auditorium, ^{o}C

$mw = Mass\ flow\ rate\ of\ water\ , kg/s$

hfg = Latent heat of evaporation , kJ/kg

U = Overall heat transfer coefficient between air and water particle, W/m^2 K

A = Area of heat transfer, m^2 (Height of tower H * Width of tower , 1 m)

LMTD = Log mean temperature for parallel flow heat exchanger, ^{o}C

where $\dot{m}$ □[kg/s] is the mass flow rate of water, consider this is a parallel flow heat exchanger where hot air and cold water is in direct with each other. The height of tower H has to be determined. The following outside design conditions are used for calculations. Dry bulb temperature of air is DBT 40 ^{o} C, Wet bulb temperature WBT 22 ^{o}C and 17% relative humidity. The inside moist cod air desings conditions is DBT 27 ^{o} C, WBT 22 ^{o} C and relative humidity of 52%. Outside velocity of air is 6 m/s. Using mass balance and energy balance equations height of tower is determined and is calculated as 6 m. The area of cross section of tower is 1 m^2. The mass flow rate of water is 127 kg/h. Heat gain in the auditorium is mainly 30 human occupants, electrical fittings 10 tubes of 40 W. Ventilation , structural load. Figure 3 shows PDEC tower at Gulbarga India.

Fig.3: Photograph of PDEC IGP office at Guberga, India

IV. CONCLUSION

PDEC towers begin to run at 11 am A significant percentage reduction in cooling electricity is achieved by using these systems. It is reported in many cases 45 %. The biggest energy saving is achieved in dry climates. Fine water droplet will improve thermal efficiency of tower. It is good solution to achieve thermal comfort where electricity is acute shortage. The pump can run on solar energy using solar PV panels.

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