Experimental Study of Evaporative Cooling System

Vivek Kumar[1] Mr. Neeraj Saraswat[2]
[1]Student [2]Assistant Professor
[1]Department of Thermal Engineering
[1,2]Sunder Deep Engineering College, Ghaziabad, (U.P), India

Abstract— Cooling towers are either used for evaporation of water to get rid of heat and for cooling the operating close to the wet-bulb air temperature or within the loop case. Dry-Cooling towers rely solely on air to cool the working fluid near the dry-bulb air temperature. Applications commonly included are cooling of circulated water utilized by in Oil-Refinery, Chemical-plant, Power-station and Building-cooling. Industrial cooling tower can be utilized for removal heat from many source namely machineries or heating process materials. Large industrial towers primarily used for removal heat from circulated water system in Power-plant system, Food Processing plants, and Semiconductor plants for Industrial facilities.

Keywords: Cooling Tower, F.C.U, Temperature

I. INTRODUCTION

Cooling towers are considered as main part of most of the chemical plants. Cooling tower's fundamental work is the heat rejection in environment. Water lost by the evaporation is replenished by the make-up source for water. Cooling tower receives hot water from heat exchangers. Water coming out from cooling tower is transferred back again to the exchangers or to different units for more additional cooling.

These design guidelines helps engineers to be understood about fundamental principles for cooling towers. Cooling towers are generally employed for removal extra heat which is developed at different locations i.e. chemical plants, power stations and domestic A.Cs. These equipment has been developed as a relatively less expensive and dependable mode of low grade heat removal from cooling water.

Cooling of the circulated water is utilized by refineries, chemical & petrochemical plants, thermal plants & HAVS systems for building's cooling are Common applications of them.

A. Fan.coil.unit

A fan.coil.unit (F.C.U.) as an ordinary device consist of either a heating with /or cooling-coil or heat exchanger with a fan. This is applied in buildings used for residence, commercial use, and for industry as the part of a HAVS system. A F.C.U. is a diversified device using sometime duct work and is applied for temp. Control at installed/ multiple areas. It is either controlled by switch for on/off, manually or by thermostatically, used for controlling the through put of the water to the heat-exchanger by using a coil or the fan speed.

The output of a F.C.U. is situated by observing the temp. Of the air entering and leaving from the unit i.e. the air volume being passed through the unit. It is the simple statement with more readings there at sensible heat ratio, air's specific heat capacity by which thermal performance is affected.

B. Cooling Tower

Cooling towers are devices used for heat removal by transferring processed waste heat to the environment. As the concept of evaporation is used by cooling towers so small amount of the water get evaporated into the stream of moving air by subsequent discharge in the environment. Which results the cooling of remaining water significantly.

II. LITERATURE REVIEW

Dileep KJ and, Dileep Kumar Baniya, "Design and Fabrication of Cooling Tower" (2017)-Cooling tower is a heat rejection device. It is used to dissipate waste heat into the atmosphere. This paper is all about the developing a cooling tower that cools the hot water coming from the different equipment in energy conversion lab. In energy conversion lab, there are total five equipments from which we are getting hot water while conducting the experiment. Due to hotness the water is not suitable for experimentation. So the hot water is directly released into the ground without being recirculated. This necessitates the development of cooling tower to cool the water. For this purpose a tank used where the hot water coming from the different equipment gets collected. The hot water is then supplied to the cooling tower for cooling by the use of motor pump. The cooling effect is obtained by the natural air which is entering in the gap provided by the louvers. After the water is cooled it gets collected in another tank which is kept at the bottom of the cooling tower. The cooled water is recirculated into the equipment for conducting the experiment.

Vishnu S. Kumar and Reji Mathews, "Performance Analysis and Optimization of Cooling Tower" (2018)-Cooling tower is an integral part of every thermal power generation plant. Inlet water temperature and mass flow rate of water and air are having main influence on the performance of counter flow induced draft cooling tower. Effectiveness of the cooling tower can be increased up to 20% by optimizing the liquid to gas ratio (L/G) of the cooling tower. Likewise other parameters such as range, tower characteristic ratio can also be increased considerably.

Sunil J. Kulkarni and Ajaygiri K. Goswami, "Studies and Experimentation on Cooling Towers: A Review" (2015) - In induced draft cooling towers, air is sucked from other end. The water cooling happens because of humidification of air. The heat lost by water is heat gained by air. Water recirculation is also important aspect in the cooling towers. The effectiveness of cooling tower depends on flow rates of air and water and water temperature. Minimization of heat loss is one of the important aspect of studies carried out by various investigators. The interfacial area between air and water is also crucial factor in cooling towers. Three types of packing used in cooling towers are film, splash and film-grid packing. Also it was observed that drift is one of the

important losses in cooling towers. Various shapes of cooling towers are tried by various investigators to study effectiveness. Hyperbolic shape was advantageous due to higher area at bottom. It provides aerodynamics, strength, and stability. The present review is aimed at summarizing studies and research on cooling tower for increasing efficiency and power savings to make it more economical and efficient.

Pushkar R. Chitale and Rohan K. Gamare, "Design and Analysis of Cooling Tower" (2018)-. Cooling Tower Works On The Principle Of Evaporative Cooling In Which Water Is Cooled Down By The Impact Of High Velocity Flowing Air. It Offers An Effective Alternative At Locations Where There Is Cooling Water Scarcity And Where Hot Water Discharge Causes An Environmental Concern. The Effective Cooling Of Water Depends On Various Process Parameters Like Dry Bulb And Wet Bulb Temperature Of Air, Fill Material And Its Size, Inlet Air Flow Rate, Air Inlet Angles, Water Flow Rate And Temperature Etc. The Present Paper Is The Detailed Methodology Of Design Of Counter Flow Cooling Tower Based On The Input Process Parameters By Considering Different Types Of Possible Losses.

III. EXPERIMENTAL SETUP

Evaporative cooling is that process in which warm water coming from the process of an industry is pumped up to the cooling tower's top in which system for distribution of water is employed. Here the cooling tower's nozzles distribute the water to the wet deck and simultaneously air is drawn through the air inlet, louvers that force water to be evaporated. Evaporation is caused the removal of heat from the makeup-water.
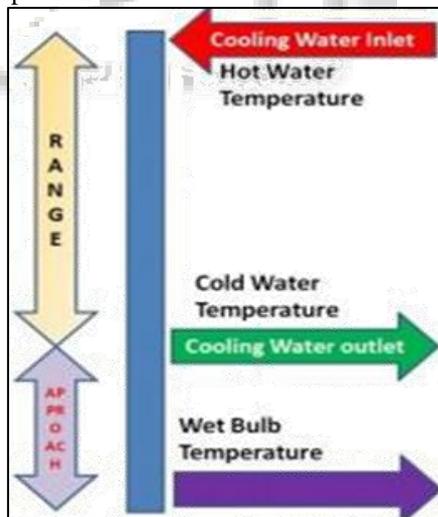

Fig. 1: Cooling Process

Fig. 2: Cooling Tower

A. Components

There are many components used in the Fan Coil Units. The component used in the fan coil unit are as follows.
1) Fan
2) Coils
3) Motor
4) Shaft.

1) Fan

Flow within a fluid (mainly in gas such as air) is created by a fan. The fan integrated with a rotating-assembly of vanes / blades which work on the fluid. The rotating blades and hub assembly is called as an impeller-rotor-runner. Generally, it is enclosed by a form of housing /case. Which may direct the air-flow or increasing safety by preventing contact of objects with the fan blades. Mostly electrically operated motors are employed with fans but another sources (including I.C. engines) may also be used for power,

High-volume and low-pressure flow is developed by fans (mainly more than ambient pressure), opposed by compressor that produce high-pressure at a relatively low-volume. Wind turbine with designs similar to a fan rotate a fan blades exposing to a fluid stream.

Complex applications included, climate-control and personal-thermal-comfort (e.g., as an electric-table /floorfan), engine-cooling system of vehicles(e.g., radiator front), machine-cooling-systems (e.g., inbuilt-computer and audio-power-amplifier), ventilations, fume extractor, (e.g., separating-chaff for cereals and grain), dust removal (e.g. as vacuum cleaner), drying (generally with combined by a heating-source) and fire-draft provider.

Generally fans utilized for cooling people and not really for cooling air (anyway an electric. fan warms it slightly due to the warming of its motor) but in case of evaporating- cooling- sweat that increase convection of heat in atmospheric air due to the air-flow from the fans and therefore fans may be in-effective for body-cooling if the surrounded-air is at near the body temp. And containing high-humidity. At the time of very high heat and humidity, it is really advised not to use fans.

2) Coils

The core to an A.C. system is a refrigerant. Gas which goes through gaseous. State to liquid. State by the process of compressing and again then changing into gaseous state by the absorption of available heat in the room. It going through a refrigeration-process that is divided into four main parts:

3) Compression

The gas is converted into a high. Pressure, hot. Liquid when pressurized.

4) Condensation

High-pressure, hot-liquid-refrigerant is converted in cool-liquid by releasing heat into the outside. Air after flowing through a coil e. It is the part using coils.

5) Expansion-Valve

High-pressure liquid is converted into low-pressure liquid by a valve.

6) Evaporation

An evaporating coil again receives this low-pressure liquid, where heat is absorbed from the room and it converts from liquid to gas. In case of split A.Cs this process takes place in the in-door unit while all other processes in the out-door unit.

Principally the heat is transferred from the inside. Air to outside. Air and this heat-transfer take place in the coils. The refrigerant evaporates (changes into gas from liquid) in the evaporation-coils by absorbing the heat from the air (inside the room) by passing-over it. The air (inside the room) cooled by this process and directed into the room. The gaseous. Refrigerant then goes through the compression and then condensation in coils where it condenses by released heat into the air surrounding it. Exhaust fans blow out the warm air.

This working-principle for all types of H.V.A.C. systems remains same only the size of the system keeps changing. Thus the efficiency of H.V.A.C. systems is affected by the type of coils used, the. size of the coil, the material used for making, cleaning and maintenance ease etc. All play an important role in the functioning of an H.V.A.C. systems.

IV. EXPERIMENTAL CALCULATIONS & RESULT

A. General Objective

Conceptual designing for an Evaporative cooling system for domestic purpose up to some extent of physical comfort level by the concept of a Cooling tower and a Fan coil unit in which cool water is circulating in place of refrigerant.

B. Cooling Load

Total cooling load consist of External and internal loads, both of them consist of sensible as well as latent components.

Length of room= 3 m
Width of room= 3 m
Height of room= 3 m
Occupants= 02
Fan (200W) = 01
Tube light (100W) = 01
Overall heat transfer coefficient of wall (U) = 0.20 W/m²K
Sensible heat transfer from occupant's body to surrounding = 85W
Latent heat due to evaporation and respiration of body = 35W
Heat transfer through opaque surface = $U*A*\Delta T$
= $U*A*(t_1 - T_r) = 0.20*54*(32-29.5) = 27W$

Internal load = Load due to occupants + Load due to lighting and other appliances
= (85 + 35)*2 + (100 + 200) = 540W
Total Load = (27 + 540) = 567W = 0.567 KW

C. Cooling Tower Sump Water Capacity

Length = 47 cm
Width = 46 cm
Height = 15 cm
Volume = l*b*h = 47 * 46 * 15 = 32430 cm³
= 32.43 liters

D. Power Consumption

Blower motor = 150W (1450 rpm, 420 CFM)
Exhaust fan motor = 160W (2300 rpm)
Sump water pump = 18W (Head ht.1.6m)
Flow rate 1100 LPH)
KWH = Watts * Hours / 1000
= (150 + 160 + 18) * 1 / 1000
= 0.33 unit per hour

E. Calculations for Cooling Tower

1) Values from Observations

Wet bulb temperature (Twb) = 24 ºC
Dry bulb /Ambient air temperature (t_1) = 32 ºC
Outlet air temperature of cooling tower (t_2) = 31 ºC
Inlet water temperature in tower (T_1) = 31.0 ºC
Outlet water temperature from tower (T_2) = 27.0 ºC
Mass flow rate of water (Mw) = 1100 L/hr.
= 1.1 m³/hr. = 1100 Kg/hr. = 0.305 Kg/sec
Spec. ht. capacity of water (Cpw) = 4.186 KJ / Kg ºC
Room temperature (Tr) = 29 ºC

2) Values from Psychometric Chart

Specific volume of air at inlet (Vs_1) = 0.8868 m³/Kg
Specific volume of air at outlet (Vs_2) = 0.8877 m³/Kg
Specific humidity at inlet (Wa_1) = 0.0155 Kg/Kg
Specific humidity at outlet (Wa_2) = 0.0186 Kg/Kg
Enthalpy of air at inlet temp. (Ha_1) = 72 KJ/Kg
Enthalpy of air at outlet temp. (Ha_2) = 80 KJ/Kg
Enthalpy of room air (Hr) = 63 KJ/Kg
Specific volume of room air (Vsr) = 0.87456 m³/Kg

3) Cooling Tower Approach

CTA = Outlet temp. Of water - Wet bulb temp.
= (T_2 - Twb) = 27.0 ºC – 24.0 ºC = 3.0 ºC

4) Cooling Tower Range

CTR = Inlet temp. Of water - Outlet temp. Of water
= (T_1 - T_2) = 31.0 ºC - 27.0 ºC = 4.0 ºC

5) Efficiency of Cooling Tower

η = Range / (Range + Approach)
= (T_1 - T_2) / (T_1 - Twb)
= 4 / (4 + 3) = 0.571 = 57.1 %

6) Heat Loss by Water

H_L = Mass flow rate * Specific heat of water * Change in water temperature
H_L = $Mw*Cpw*(T_1 - T_2)$
= 0.305 * 4.186 * (27.8 – 27.0)
= 3683.68 KJ/hr. = 1.023 KW

7) Volume of Air Required

V = (H_L*Vs_1) / [(Ha_2-Ha_1)-(Wa_2-Wa_1)$*Cpw*T_2$]
= (3683.68 * 0.8868) / [(80 - 72) – (0.0186 -0.0155)
* 4.186 * 27] = 3266.687 / [8 – 0.350368]

= 3266.687 / 7.649632 = 427.0385 m³/hr.

= 7.12 m³/min.

8) Mass Flow Rate of Air

$Ma = V/Vs_1 = 427.0385 / 0.8868$

= 481.5499 Kg/hr. = 0.134 Kg/sec.

EVAPORATIVE LOSS (Generally 0.2% of mass flow rate of water for every 1°C temperature drop)

$E_L = 0.2 * Mw * (T_1 - T_2)/100$

= 0.2 * 1100 * (27.8 – 27.0)/100

= 1.76 Kg/hr.

9) Calculations for Fan Coil Unit

Inside air condition for room

Room temperature (Tr) = 29 °C

Relative humidity (R.H.) = 55 %

Enthalpy of room air (Hr) = 63 KJ/Kg

Specific volume of room air (Vsr) = 0.87456 m³/Kg

Volumetric circulation rate of air required (Vr) = 0.4 m³/min. per person

Mass circulation rate of air (Mr) = Vr / Vsr

= 0.4 * 2 / 0.87456

= 0.91475 Kg/min.

= 0.0152 Kg/sec

Outside air condition for room

Ambient air temperature (t_1) = 32 °C

Wet bulb temperature (Twb) = 24 °C

Enthalpy of ambient air (Ha_1) = 72 KJ/Kg

10) Heat Transferred By Room Air

$Qr = Mr (Ha_1 - Hr) = 0.0152 (72 – 63)$

= 0.137 KJ/sec   = 0.137 KW = 137 W

F. Cost for Experimental Setup

S. No.	Description of Items	Cost
1	Fan Coil Unit	2500
2	Exhaust fan motor	1500
3	Cooling Tower Body	1000
4	Temperature sensing switch (TSS)	500
5	Sump motor	200
6	Stand	300
7	Wires, Switches, Pipes, Clamps, Fill pads and other items required for assembly	500
	Total cost for the system	6500

Table 1:

G. Observation Table

S. No.	ROOM TEMP. (Tr)	INLET TEMP. OF COOLING TOWER (T_1)	OUTLET / SUMP WATER TEMP. (T_2)	TIME IN HOURS
1	31.2	31.0	31.0	00:00
2	30.0	29.6	28.8	00:15
3	29.7	28.8	28.0	00:20
4	29.4	28.5	27.7	00:25
5	29.3	28.2	27.3	00:30
6	29.1	28.0	27.2	00:40
7	29.0	27.9	27.0	00:50
8	29.0	27.8	27.0	01:00

Table 2:

V. RESULT & CONCLUSION

1) It is difficult to achieve the higher efficiency for a small prototype.
2) Higher cooling may be achieved by few changes in the design of FCU and by changing the composition of circulating water by mixing with coolant.
3) Cost as well as power consumption of the setup is low as compared to the Air conditioning system.
4) It might be a positive approach for the designing of an alternate of Air conditioning system up to some level of desired cooling comfort.

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