ESTIMATION OF AN AIR FLOW RATE FOR AN AIR WASHER IN EVAPORATIVE COOLING SYSTEM

A minor project report submitted to
Jawaharlal Nehru Technological University
In partial fulfillment of the requirement for the end of degree of

BACHELOR OF TECHNOLOGY

in

MECHANICAL ENGINEERING

Submitted by

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CERTIFICATE

This is to certify that the Mini-Project entitled "**ESTIMATION OF AIR FLOW RATE FOR AN AIR WASHER IN EVAPORATIVE COOLING SYSTEM**" is being submitted by **MR. MAHOMMAD ASIF (18WJ1A03C9), MEDIDODDI KARTHIK (18WJ1A03C2), MD ABDUL RAHMAN SHAIK (18WJ1A03C1)** in partial fulfillment for the award of the Degree of Bachelor of Technology in Mechanical Engineering to the Jawaharlal Nehru Technological University Hyderabad is a record of bonafied work carried out by team under my guidance and supervision.

The results embodied in this Mini- Project report have not been submitted to any other University or Institute for the award of any Degree or Diploma

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DECLARATION

We declare this mini project report titled " **ESTIMATION OF AIR FLOW RATE FOR AN AIR WASHER IN EVAPORATIVE COOLING SYSTEM**" submitted in partial fulfilment for the award of the degree in partial fulfilment for the award of the degree of bachelor of the technology in mechanical engineering to the Jawaharlal Nehru technological university, Hyderabad is a record of original work carried out us under the guidance of **Mr. J Kishore,** Asst. Professor, Department of mechanical engineering, and has not formed the basis for the award of any other diploma, in keeping with a ethical practice in reporting scientific information, due acknowledgement has been made whenever the findings of others have been cited.

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ABSTRACT

This project develops an approach for the effective analysis for air washer. The approach can be used for simultaneous heat and mass transfer in air washers operating as evaporating coolers.

By using proper technique, the solution has been obtained for the air washer. The solution gave an excellent match with the results available in the literature. The performance study of air washer was carried out by varying several essential parameters such as inlet humidity ratio, air flow rate, water inlet temperature and inlet air dry bulb temperature.

The variation of outlet air temperature with respect to water inlet temperature was investigated under different inlet humidity ratio, mass ratio, inlet dry bulb temperature and length of air washer.

It was observed that the efficiency of air washer will increase by reducing inlet water temperature air flow rate and inlet humidity ratio.

Further, the results show that the effect of inlet water temperature on the air outlet temperature is more for the larger air washer length. The effect of spray air ratio on outlet air temperature decreases as the water inlet temperature increases and this effect becomes zero at particular inlet water temperatur

CHAPTER 1
1.INTRODUCTION

1.1 The Importance Of Air Conditioning

In today world global warming is one of the biggest problems faced by human. The maximum temperature during the summer has been increasing every year. Different types of air conditioning systems are used in today's world based on different principles of thermodynamics.

The field of air conditioning has become increasingly important in the last few years. industries concerned with the construction of air conditioning apparatus have expanded rapidly because of the increased need of equipment, this presents the realization of a great opportunity for engineers with the proper background and training.

The use of air conditioning in industry and public enclosures has increased in large proportions. Some of the important applications are as follows:

1.Controlled humidity in the manufacture of confectionery the processing and weaving of artificial silk, and the printing and lithographing industry. 2. Controlled humidity and temperature in automatic wrapping machines, used for wrapping food products (cigarettes and confectionary).

3.Controlled temperature of reaction and controlled facilitating and retarding of the evaporation in certain branches of chemical industry.

4.Control of the moisture content or air supplies to blast furnaces in manufacture of Pig iron.

5. Air conditioning for human comfort in deep mines, in glazed iron ware manufacturing and in the lithographing industry.

6.Air conditioning for human comfort and perishable food preservations in hotels, restaurants, other public enclosures, and private homes.

7.Air conditioning for human comfort in theaters, office buildings, other public buildings where large groups of people may gather.

8.Air conditioning for human comfort in the aircraft, locomotive and other transportation Industries.

Air conditioning may be considered to be the simultaneous control or all or at least the first three of the following factors which affect the physical and chemical conditions or the atmosphere within any Structure. These factors most of which affect human health comfort include:

1.Temperature

Temperature is directly concerned with human comfort it is called thermal comfort. Thermal comfort: is the condition of mind that satisfaction with the thermal environment and is assessed by subjective evaluation. Maintaining the standards of thermal comfort for occupants of buildings or other enclosures is one of the important goals of HVAC design engineers. "Thermal neutrality is maintained when the heat generated by human metabolism is allowed to dissipate. This maintaining the thermal equilibrium with the surroundings. Temperatures of places vary with change in altitude, weather, climate and horizons.

Room temperature is colloquial expression for the typical or preferred indoor temperature to which people are generally accustomed. It represents the small range of temperature at which the air feels neither hot nor cold, approximately 70^{0} F ($21\ ^{0}$ c)

2. Humidity

Relative humidity levels below 25%' are associated with increased discomfort and drying of mucous membranes and skin, which can lead to champing and irritation. low relative humidity also increases static electricity which causes discomfort and operation of computers and paper processing equipment. High humidity levels can result in condensation within building structure and on interior and exterior surfaces and the subsequent development of moulds and fungi.

3.Motion

Air movement is an important factor in thermal comfort. whilst stagnant air in artificially heated spaces often contributes to a feeling of stiffness and promotes odour build-up, even the smallest air movement in cold environments is often considered draughty. In warn or humid conditions, however, air movement can increase heat loss without any change in air temperature.

4.Distribution

Most HVAC systems heat or cool forced air. "The components and layout of mechanical air distribution important because they can improve both the comfort of occupied spaces and reduce energy use. Although the fans that distribute the air do not consume nearly as much energy s the equipment that generates the heating and cooling. It does not matter how efficient the equipment if the air is not distributed well, further leakier duct work cause2040% of heating and cooling energy loss. Successful air distribution is measured by both its thermal comfort performance and its energy efficiency. The efficiency of air handling system Can be holistically measured by measuring the electricity use of the fans.

5. Dust

Indoor Air Quality (IAQ) is comprised by pollutants such as dust, pollen, mould, mildew and volatile Organic compounds. These pollutants can come from laboratories, cleaning solutions building occupants, health and problem begin shortly after exposure to poor Indoor Air quality. Occupants may be experienced itchy eyes, headache and fatigue. Long term exposure to poor LAQ can contribute to chronic respiratory illness such asthma.

6. Bacteria

Bacteria in our environment can cause of the illness such as typhoid, allergies and headache.

7.Odors

Odor is also associated with human comfort, bad odor is irrelevant to human we cant survive in environment with bad odor. It is mostly generated indoor by following sources:

Human sweat, cigarette, medicines, human breathe, clothing's etc.

8.Toxic Gases

The elements in home or office secretly affect health or our environment. They cause respiratory problems or allergies.

Toxic/harmful substances are:

- Toxic trio (toluene-solvent part) in nail polish,
- scented candles and metal wicks,
- Aerosol paint products,
- Chemicals in cleaning products.

Smoke of cigarette or other smoking.

A central air conditioning system implies that the equipment such as fans, coil refrigerating apparatus, heat exchangers, **AIR WASHERS**, filters, and their encasements are designed for assembly in the field rather than in the factory as a unit, A central system may be adapted for am y desired conditions, may several different enclosures from a distant central location, and is easily accessible for servicing. This Was considered to be the suitable situation for the group because the particular pieces or apparatus could be placed in use as required.

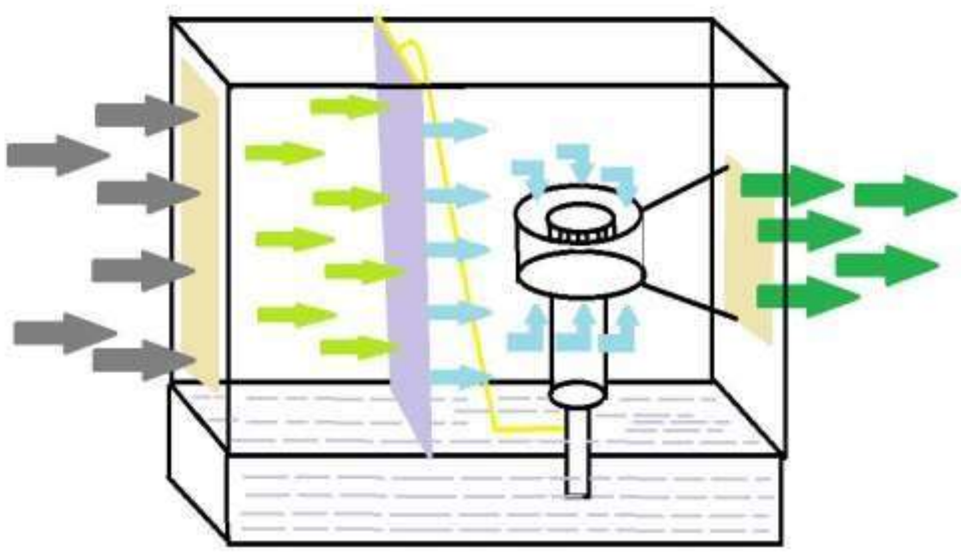
1.2 Air washer:

Air washer is one of the devices used for air conditioning. It is based on the psychrometry. It is study of the properties of moist air.

An air washer is a device used for conditioning air. As shown in Fig, in an air comes in direct contact with a spray of water and there will be an exchange of heat and mass (water vapour) between air and Water. The outlet condition of depends upon the temperature of Water sprayed in the air washer. Hence. by controlling the water temperature externally. it is possible to control the outlet conditions of air, which then can be used for air conditioning purposes. In the air washer, the mean temperature of water droplets in contact with air decides the direction of the direction of heat and mass transfer. As a consequence of 2^{nd} law, the heat transfer between air and water droplets will be in the direction of decreasing vapour pressure gradient.

In climates where the air is extremely dry, an air washer can work to increase humidity. Dry air can be hard for people to breathe. It can also contribute to the development of dry skin and may damage objects kept in environment. The air washer removes particulates from the air and adds an injection of humidity to keep the climate at a steady humidity level for increased comfort. Environments like museums and archives need precise climate control to protect their collections and an air washer can help with this. Simply using a fan to draw air over a container of cool water can scrub the air and make an environment more pleasant. Air washers draw upon this basic concept. The design can include extra features like filters to trap harmful particulates in order to increase the purity of the air.

Like other devices that clean air, an air washer can eat up a lot energy. Some are designed to be more efficient and may have features that are intended to reduce energy usage.



CHAPTER 2

2.HISTORICAL BACKGROUND

2.1 History Of Evaporative Cooling Technology

We have all the experienced the evaporative cooling effect that occurs after exiting a swimming pool on a hot sunny day. It probably did not take long past the initial discovery of cloth for early man to take practical advantage of this physical cooling behavior of water when living in hot and arid regions.

Frescoes or plaster paintings from about 2500 B.C. show slaves fanning jars of water to cool rooms for royalty. The earliest archeological trail of buildings incorporating mechanisms for evaporative space cooling starts in Ancient Egypt with paths spreading quickly to other regions having hot and dry climates. These mechanisms include the use of porous water pots, water ponds, pools, and thin water chutes integrated in various ways into thick walled and shaded enclosures to yield areas that would have been cool and provided an escape from the heat of the day.

While it is clear that our ancestors took advantage of evaporative cooling, it wasn't until more recent times that components and features could be effectively engineered to yield improved and repeatable performance results.

2.2 Uncovering the physics behind Evaporative Cooling

'The following timeline traces the history of some key scientific discoveries and developments in the science of psychometrics. using your mouse roll over the timeline to learn more:

16^{th} century	First Hygrometer	Leonardo da vinci at the beginning of the 16^{th} century was credited with inventing the first hygrometer that used a ball of wool to provide this indication of humidity level.
	First Mechanical air cooler	Da Vinci was likely the first to use a mechanical air cooler. This air cooler consisted of a hollow water wheel with an air passage constructed to guide the air from the water wheel to his patron's wife's boudoir. The air was cooled by the splashing and evaporation of water during operation of the waterwheel, Motive power was provided to move the air by the water turning a partially submerged wheel. Namely. as sections of the wheel would be submerged into the stream water level moved from the outer edge of wheel toward the center compressing the air in this chamber and forcing it to move through the passages to the boudoir.
17th century	Pascals rule for liquid pressure	Blaise pascal presented the rule: Pressure exerted anywhere on a confined liquid is transmitted unchanged to every portion of the interior and to all the walls of the containing vessel; and is always exerted at right angles to the walls.

	Boyles law	Robert Boyle developed one of the four principles that govern performance of evaporative cooling if the temperature of dry gas is constant, then its volume varies inversely with the pressure exerted on it.
18^{th} century	Fluid dynamics	Bernoulli, Euler, Pitot Chezy, and others applied the techniques of mathematical physics to develop the science of fluid mechanics. John Dalton established the nature of evaporation, and its importance to global cycle.
19^{th} century	Flow through porous media	Darcy (1856) established an understanding and quantitative characterization of flow through porous media.
20^{th} century	Psychometric charts	Willis Carrier's development of a psychrometric chart similar to ones in use today along with the development of a formula that linked the transformation of sensible heat into latent heat during the adiabatic (no external heat input or output) saturation of air.

2.3 Early Evaporative Cooling in the Southwest

Settlers of the 1920s and 1930s in the southwest slept in screened slept in screened in porches, roofs, or other outside facilities and hung wet sheets to gain some relief from the summer heat. The Arizona republic reports that guests at the ford hotel in phoenix slept on the balcony while young man peddled to power overhead fans. There were cases of pneumonia during the summer as some wrapped themselves in wet sheets and slept in front of an electric fan.

The 1996 edition of Dr. john watts evaporative air conditioning handbook identifies the origins for modern American evaporative cooling as either from the east coast or southwest. In the early 1900s, air washers were invented in the east and air coolers were developed in southwest. The air washers passes air through water spray, which cleaned and cooled the air in textile mills and factories in new England and southern coastline. coastline. The Southwestern air coolers included indirect coolers, where air passed over a water-cooled coil, and direct coolers where air was cooled by direct contact with water.

'The earliest design of the direct coolers consisted of wooden frames covered with wet burlap cloth with fans forcing air into the space being cooled. As they evolved, sumps and recirculating pumps were incorporated into the designs. After a few evaporation passes, scale would form on the pads. TO mitigate this, some of the water would be discharged or bled to a drain.

Eventually, the design for direct coolers (called wet-boxes, desert coolers, drip coolers, and then swamp coolers) evolved to the common configuration of two-inch excelsior (wood chip or aspen) pads sandwiched between chicken wire and nailed to the cooler frame. The first aspen pad (swamp) cooler was demonstrated in the Adams Hotel in downtown Phoenix June 20, 1916. In 1939, Maltin and Paul Thornburg published mimeographed instructions, "Cooling for the Arizona Home." 'The two professors at the University of Arizona had conducted tests to improve performance of these direct evaporative coolers.

About that time, early mass production of evaporative coolers began as the integrated motor and fan units manufactured by Emerson Electric Company became available. Among the very first of these mass produced coolers were from Goettle Brothers Inc. By 1939, most houses and businesses in the hot and arid southwest were using drip coolers.

By 1939, most house and businesses in the hot and arid south west were using drip coolers. By the early 1950s a large number of manufactures had joined the market and were producing coolers for a market that covered much of the USA, Canada, and offshore to countries such as Australia.

2.4 Evaporative Cooling Equipment Design challenges

Cooling for commercial applications requires large airflow rates. Early attempts incorporated larger pads and replaced the water drip application systems with slinger wheels, spray systems, or rotary pads. This step was necessary since drip systems distributed water poorly.

This condition existed in small coolers limiting their performance and was amplified in larger pads. In the slinger wheel configuration, a partially submerged, rotating wheel produces a sheet of water in the plane of the wheel. Evaporation takes place as air moves through this sheet of water and in the pads where the un evaporated water is caught.

It was quickly found that slingers were not the answer. The problem with slingers is that the density of the airborne water created by the slinger varies inversely with the square of the distance from the center of the slinger plate. This variation is further disturbed as the air stream collides with the water dependent on slinger rotation speed, direction, and the air velocity profile. Similarly, spray systems suffer from variation in physical nozzle coverage and alignment, water pressure over time, nozzle erosion, nozzle clogging, and non-uniform airstream air velocity profile.

Each of these systems failed to achieve desired air and water distribution to effectively wet the pads uniformly. Areas of the pad that are not wetted effectively allow air to pass through without being cooled and at the edges between wetted and unwetted surface establish sites for scale formation.

2.5 Improving Pad Performance

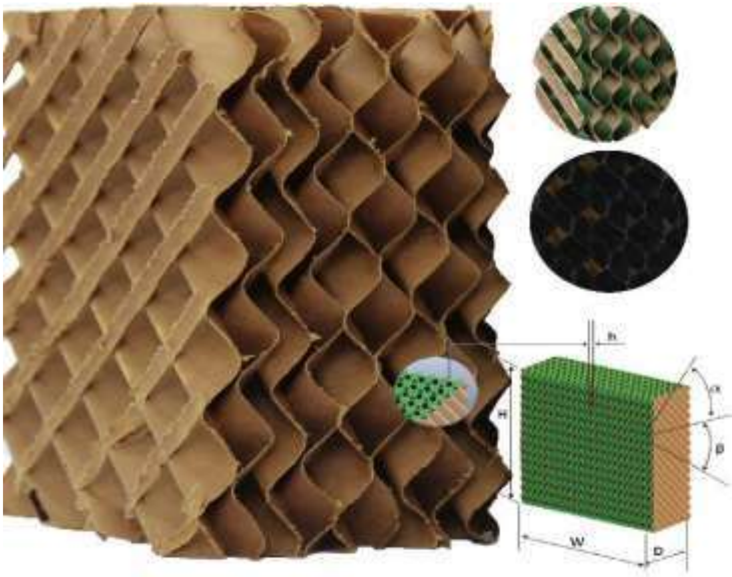
Aspen pad drip coolers provided some relief in the south west from the more than 100 f temperatures except during the monsoon season.

Additionally, these aspen pad drip coolers suffered from the following deficiencies that dramatically limited their performances:

Pad sagging	The uneven shifting and redistribution of media within the pad during operation results in channeling, hotspots, and reduced cooling performance.
Pad clogging	Loading of the pads with dust and foreign material results restricted and blocked air passage with associated channelling, hotspots, and reduced cooling performance.
Pad scaling	Non-uniform water distribution or air channelling caused uneven water evaporation and hotspots that result in scale formation and rapid performance degradation.
Moldy pad odor	The variation in pad density causes some areas to retain moisture for periods long enough to support mold growth.

Almost all drip coolers manufactured up to the 1960s featured excelsior pads made of aspen wood. Other woods were tried along with fiberglass and woven paper but each was found to have weaknesses that outweighed their advantages. Aspen pads continue to be sold today as a low-cost, limited-benefit cooling option.

In the munters introduced rigid media bonded with special glues and consisting of either glass-fibre materials or thin corrugated Sheets of Strong cellulose (paper) impregnated with chemicals to resist sagging and decay, Rigid media could maintain its shape and support its own weight when wet.



The photo above shows a sample section of rigid media on the left and aspen pad on the right.

2.6 Recirculating Coolers Both Solve and Introduce Issues

Wetting the thicker rigid media pads required a shift from multiple tube "spider" drip systems (used in swamp coolers) to top-mounted pipes with evenly spaced holes and higher recirculating flows. angles 0t- the corrugations in the rigid media were patented by Munters to achieve effective air and water interaction in the Channels, which promotes water vaporization while limiting the air-induced migration of water to the back of the pad that creates dry spots on the face of the pad.

'The benefit of a recirculation system is that the now directed over the media can be sufficiently higher than the evaporation rate to achieve a reasonable distribution and minimize the size of un-wetted meas. However, these systems bring their own set of design requirements and performance issues. Some of the more significant of these issues are identified below:

l. Water collection and storage sump must be located in the cooler under the media, which limits the options for cooler size and location and requires additional structural support due to the additional weight of the cooler.

2.The sump water level must be maintained and cooler manufacturers typically select low cost, unreliable, and high maintenance float switches similar to those found in the household toilet to serve this function.

3. The higher recirculation flow rate increases the volume of water at the air to water interface, which increases the tendency for water entertainment and carry over at lower air velocities.

4. The higher water flow rate creates a water blanket, which limits heat transfer and water vapor migration.

5. The higher water flow rate and constant immersion of the media in water reduce the effective life of the media by wash the rigidifying agents from the media at an accelerated rate.

6. Draining the sump at startup and shutdown takes significantly longer. Not draining the sump in that sequence creates stagnant water that supports the growth of algae and mold. These molds are not only unhealthy but are typically accompanied by a stale odor.

7. No provisions are incorporated ill recirculation systems to remove the foreign material that washes out other air and into the sump. 'Therefore, this material either stays in the sump or is re-circulated and deposited on the media. Re-depositing the material on the media reduces heat transfer and increases the rate of scale formation.

8.Many schemes have been instituted to set and control the water bleed rate for recirculating coolers in an attempt to limit scale formation. The result achieved is that scaling continues to be a significant problem and water usage is high.

Alternative Evaporative Cooling Cycles

A few companies have offered once-through systems as an alternative to the re-circulating water system. These once-through systems have benefits over the re-circulating systems, however only AZ Flow has solved the water distribution issue and has an analog or continuous control or the full range of possible temperatures and relative humidity. Unlike AZ Flow, these cooler systems use more water than the recirculating systems, have a shorter media life, and experience poorer codling performance.

CHAPTER 3

3. Principle and Work Application of Air Washer

3.1 The Air Washer

In order to fully understand and interpret correctly the terms used in connection with the air washer, it is desirable that the terms be defined at this point.

An air washer may be thought of as an enclosure in which air is drawn or forced through a spray of water in order to cleanse, humidity, or dehumidify the air. Cleansing the air refers to the removal or airborne impurities such as dusts, gases. vapours, fumes, and smoke. The increase in water vapor in a given space is called humidification, and the decrease of water vapor in a given space is the process of dehumidification.

3.2 The Psychometric Chart

The psychrometric chart provides a convenient means of representing the different processes which are possible in the operation of an air washer and can be used to solve the problems of air conditioning which involved-

The psychrometric chart shows graphically the properties of air on the basis of one pound of dry air (air free of water vapour) at standard atmospheric pressure, 29,92 inches of mercury, Psychrometric pertains to psychrometry or the state of the atmosphere with reference to moisture. The air properties obtainable from the psychometric chart are represented in figure 1, their definitions being found below. This particular chart in universal is that it has corrections for barometric pressure other than standard and enthalpy deviation lines for corrections of enthalpy of air for non-saturated conditions.

The following are definitions of the properties of the moist air found represented on the psychometric chart:

1. saturation temperature (T-S). Temperature of saturated air at a particular vapor pressure.
2. Dew-point temperature(T-DP). Temperature at which condensation of moisture begins when the air is cooled.
3. Enthalpy at saturation or total heat (TH). A thermal property indicating the quantity of heat in the air above an arbitrary datum, in BTU per pound of dry air. The datum for dry air 0 F and for the moisture content is 32 F water.
4. Enthalpy deviation (d) deviation of enthalpy of unsaturated air from that of saturated air.
5. Relative humidity (RH). Ratio of actual water vapor pressure in air to the pressure or saturated water vapor in air at the same temperature.

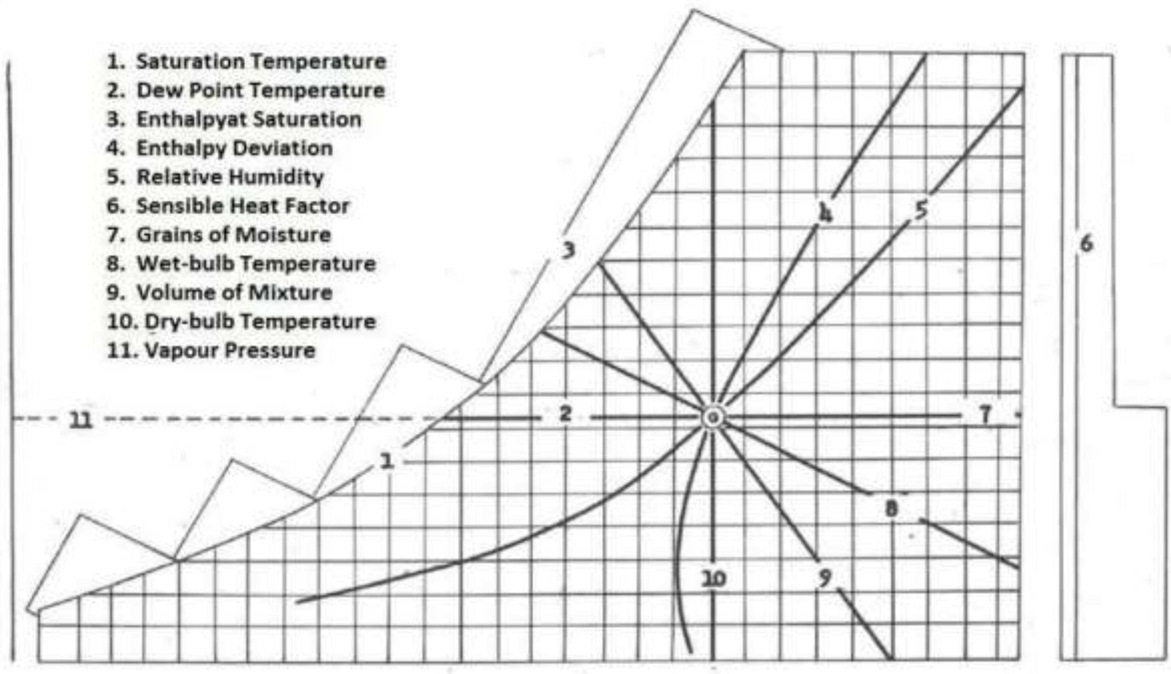


Fig: psychometric chart

6. sensible heat factor. The ratio of sensible heat to total heat load. Sensible heat indicates that portion or heat which changes only the temperature of the substance involved. latent heat is a term used to express the energy involved in a change of state.
7. Grains of moisture or specific humidity. The weight of water vapour in grains or pounds per pound of dry air.
8. Wei-bulb Temperature (T-WB). Temperature registered on a thermometer whose bulb is covered by a wetted wick and exposed to a current of rapidly moving air.
9. Volume of Mixture (v). Cubic feet of the mixture per pound of dry air.

10.Dry bulb temperature. Temperature of air as registered by an ordinary thermometer.

11. vapor pressure. The pressure exerted by the water vapour contained in the air in inches or mercury.

It may be noted from Figure I that the dry-bulb, wet-bulb, and dew point temperatures, and the relative humidity are so related that when any two are known, all the other properties represented on the psychrometric chart can be read.

When air Is saturated, contains all the water vapor it can hold at a given dry-bulb temperature, the dry-bulb, wet-bulb and dew point temperatures are the same, and the relative humidity is per Cent.

3.3 Adiabatic Saturation

Because the wet-bulb thermometer is important in psychometric, it is necessary to understand the basic process behind the result in measurement.

When air below saturation is brought into contact with water, some or the water will vaporize, adding to the moisture content or the air. It no heat is added moisture will be supplied entirely at the expense of the heat of the air and of the superheat or the original quantity of water vapour.

Evaporation will continue and the temperature or the air will be lowered until the air is saturated with the water vapor. This process, taking place without heat transfer to or from an outside source, is called adiabatic, end the final temperature that is approached is termed the temperature of adiabatic saturation or the wet bulb temperature.

Actually, the mixing or water vapor and air at the wetted surface of a wet bulb thermometer is not adiabatic because the bulb “sees” objects at the dry bulb temperature. The result is a radiation error and a higher reading than the true adiabatic saturation temperature.

Also, because of the difference of rate of diffusion between the air and water vapor, a wet bulb thermometer will tend to read lower than the true temperature of adiabatic saturation.

Hence, the errors are largely compensated and account for the largely close agreement between the observed wet-bulb temperature and the true temperature of adiabatic saturation.

3.4 Heat Exchange between Air and Water

When air is brought into contact with water at a temperature different than the wet bulb temperature of the air; there will be an exchange or heat, as well as moisture, between the air and water. In any exchange of heat between air and water, the temperature of the water can never Fall below the initial wet-bulb temperature of the air if the initial water temperature is greater than the initial wet-bulb temperature. Also, the converse is true; if the initial water temperature is below the initial wet-bulb temperature of the air, the final water temperature will never rise above the initial wet bulb temperature.

This relationship is shown in Figure 2, the diagram is shown as parallel now because the test air washer was of this type. There is only one exception to the rule that whether there is an exchange of heat occurring when air is brought into contact with water, the temperatures of both must change. This occurs in an air washer when the spray water is continually recirculated without external heating or cooling.

The temperature of the spray water will soon assume the initial wet-bulb temperature and will not change thereafter. Aside from this, there is always Change in the temperature of the Spray water when it is brought in contact with air. In order to humidify air with spray water. the temperature of the spray water must be higher than the required final dew point temperature of the air. Such an amount of water must be used that, as the water cools from its initial temperature, its final temperature will still be above the required final dew point temperature.

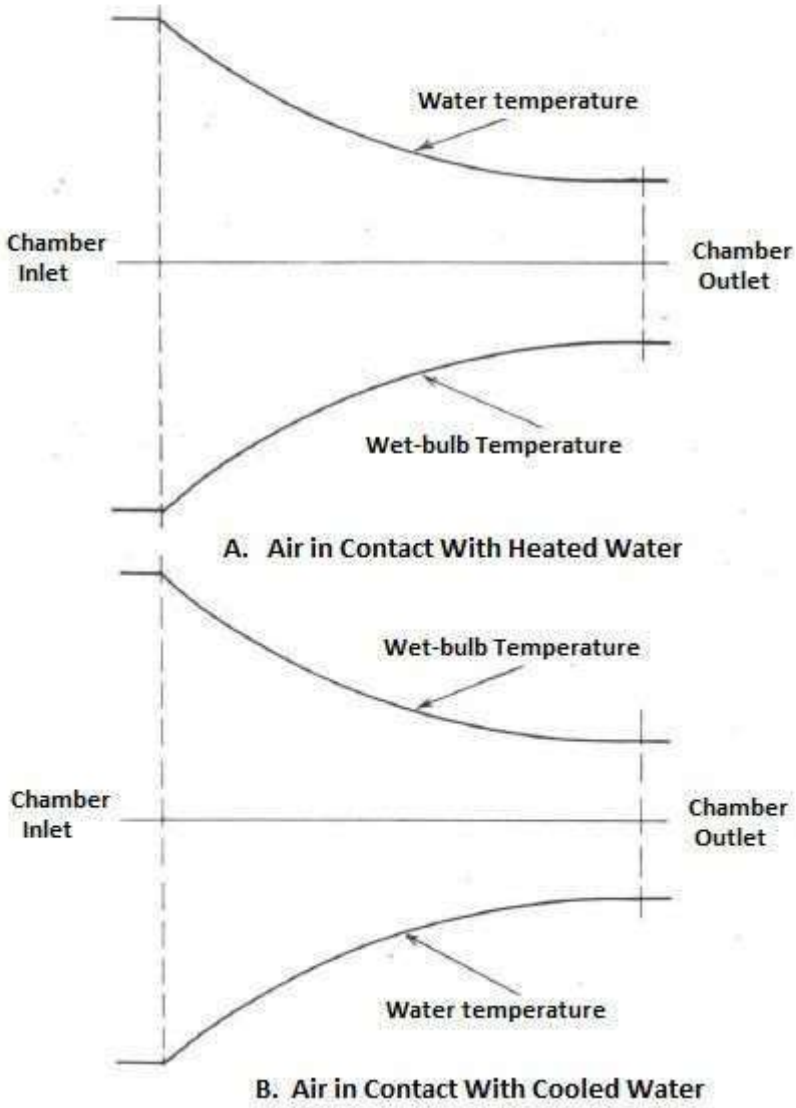


Fig: parallel flow of air and water through a spray chamber

When dehumidifying, the exact converse is true the final water temperature must be below the required final dew point of the air.

Thus for the relation between the dew-point temperature of the air and the water temperature has been discussed. In addition, the relationship between the temperature of the water and the initial dry-bulb and wet-bulb temperatures of the air must be discussed.

There are five general cases which can possibly be simulated in an air washer. The final air condition in each case depends entirely upon the characteristics and construction of the particular air washer in use. The five cases are as follows:

1. The temperature of the water is higher than the initial dry-bulb temperature of the air.
2. The temperature of the water is at a point between the initial dry-bulb and wet-bulb temperatures of the air.

3. The temperature of the water is at a point between the initial wet-bulb and dew-point temperatures of the air.

4. The temperature of the water is lower than the initial dew-point temperature of the air.

5. The temperature of the water is constant and equal to the initial wet-bulb temperature of the air. This is the only case in which there is no variation in water temperature.

Case 1

If the temperature of the water could be maintained at a constant point above the initial drybulb temperature of the air, the dew-point, wet-bulb, end dry-bulb temperatures of the air would increase, represented by line AC.

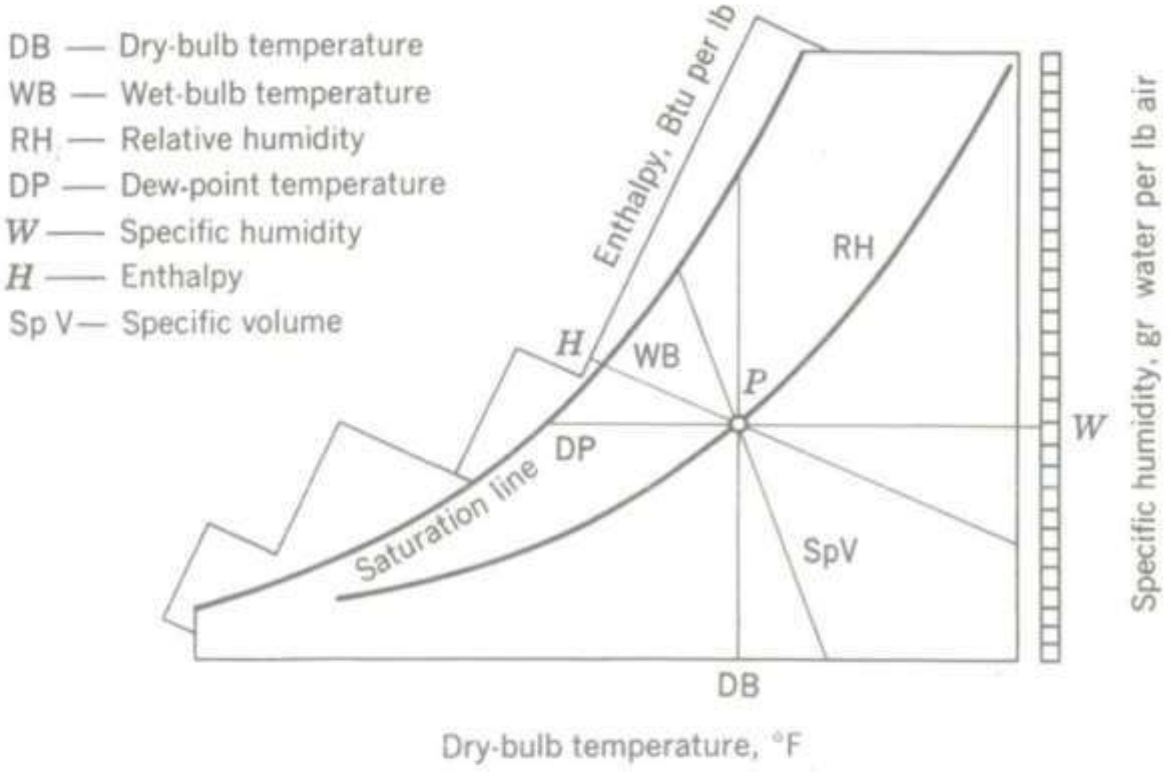
Point A represents the initial state of the air, point B the final condition of the air leaving the spray chamber, and point C the constant temperature of the water. The water temperature can be represented on the psychrometric chart by a point located on the saturation curve.

As the air passes through the spray chamber, its condition is always represented by a point on the line AC. This point moves toward C from the initial condition A.

The air leaves the spray chamber at some final condition B. The longer the air is in contact with the water the closer B will approach c.

In the actual case, the water temperature is not kept constant but drops as it heats and humidifies the air. Thus, a straight line no longer represents the coalition of the air, but a curve such as AD will represent the air condition.

The point E represents the final condition of the air. The curve CD represents the falling water temperature with point D being representative of the final temperature of the water.



Case 2

If the water temperature could be held constant at a temperature between the initial dry-bulb and wet-bulb temperatures or the air, the condition or the air could be represented by a point traveling from point A toward G on line AG as it passes through the spray chamber.

The point F represents the final air temperature and G the constant water temperature. When the water is allowed to cool to such a point that its final temperature lies between the initial dry-bulb and wet-bulb temperatures of the air, the air will be both cooled and humidified.

The dry-bulb temperature of the air will drop but its wet-bulb temperature will rise. The increase in the wet-bulb temperature is caused by the fact that the latent heat gain by the air is greater in amount than the sensible heat that it loses. In this case, the condition of the air can be represented by a point located on the curve AH . Point A is the initial air condition, point I the final air condition, and point H the final water condition.

If the air is to be both heated and humidified, the initial end final temperatures of the water must both be kept above the final dry-bulb temperature of the air. On the other hand, it the air is to be humidified without being heated, the final temperature of the water must fall to a point equal to or below the initial dry-bulb temperature of the air. this can be readily seen by referring to the diagram or the psychrometric chart. There is one important fact that applies to both Cases 1 and 2. When water in contact with air cools, it surrenders heat and moisture to the air and the final temperature to which the water can be cooled is higher than the final wetbulb temperature of the air.

Case 3

It the water temperature could be held constant at a temperature lower than the initial wetbulb temperature but higher than the initial and final dew-point temperatures of the air, the condition of the air could be represented by a line AK in Figure 3. Point K represents the constant water temperature end point K the final air condition.

It the water temperature is not constant as in the case in the air washer, but changes as the water flows through the spray chamber, the condition of the air can be represented by a point on the curve AL. Point M on the curve is the final air condition end point L the final water temperature. The temperature or the water rises in spite of the fact that it is humidifying the air.

In this case the air surrenders sufficient sensible heat to warm the water and also to evaporate a small part of it. The condition curve, in this case, sweeps upward to the right, whereas in Cases 1 and 2 the curves turn outward and to the left. If the initial water temperature is below the initial wet-bulb temperature of the air, the water temperature will rise, thus bending the curve upward to the right.

It the initial water temperature is above the initial wet-bulb temperature of the air, the water temperature will fall causing the representative curve to bend down to the left. Because, in this case, the initial water temperature is below the initial wet-bulb temperature of the air, the water temperature will rise and both the dry-bulb and wet-bulb temperatures of the air will fall.

The maximum possible final water temperature lies below the final wet-bulb temperature of the air.

Case 4

If the water temperature could be held constant at a temperature below the initial dew-point temperature of the air while in contact with the air cooling and dehumidification of the air would take place along a line such as AO. Point N represents the final air condition and Point 0 the constant water temperature.

In the actual case, the water temperature will rise while it is in contact with the air. This is represented by the curve OP on the saturation curve in the diagram. The condition of the air will be represented by the curve AP, with point Q as the final condition or the air.

In this case the water will dehumidify the air if sufficient water is provided to hold the final water temperature down to a point below the initial dew-point temperature of the air. It the final water temperature is allowed to rise above the initial dew-point temperature or the air.

The air will be cooled, but it will be humidified as well. The final water temperature cannot rise to the final wet-bulb temperature of the air.

Case 5

In this case, the water is constantly re-circulated without being heated or cooled by an external source. When the initial water temperature is the same as the initial wet-bulb temperature or the air, the temperature of the water will not change as it is brought in contact with the air.

Water that is continually re-circulated without being heated or cooled from an outside source will soon assume the wet-bulb temperature of the entering air.

The water temperature will then remain constant as long as the initial wet-bulb temperature is not changed. Evaporation or moisture must take place, however, since the temperature or the water is above the dew-point temperature or the air.

In addition, since the water temperature is below the dry-bulb temperature of the air, there must be a drop in the dry-bulb temperature or the air-. There is no change in the total heat content of the air and no change in the wet-bulb temperature in this case.

Thus, the process is called adiabatic saturation. The latent heat required for the evaporation of the water can be obtained only from the sensible heat that the air loses as its dry-bulb temperature fall. The air loses sensible heat but gains an equal amount of latent heat.

The process of adiabatic saturation can be represented by a straight line AS in Figure 3 because the water temperature is constant. The process can be represented on the line coinciding with the wet-bulb line on the psychrometric chart since there is no change in total heat content.

Point B represents the final air condition. This case is important because the motion is applied commercially on a large scale. Air washers utilizing this principle are in wide used for humidification in winter.

3.5 Application of air washer:

- Comfort conditioning suitable for malls, hotels, garment units, engineering units, etc..
- Industrial ventilation cooling.
- Pre cooling for compressor and gas turbines.
- Hybrid air conditioners.
- 100% fresh air application.
- Dust removal application.

CHAPTER 4

4.Project Work

4.1 Objective of project:

The air washer., because it is of a new design and of different construction than ordinary air washers, is of particular interest. Thus, it was the decision of group that the particular characteristics of the air washer, as set up in this system, might be of considerable value. Not only for future instruction purposes, but also in the addition of equipment desired for RAC Laboratory development and expansion of the institute.

The thermal and flow characteristics of the air washer are considered to be of primary importance. It is recognized that this information would be needed in the near future. Therefore, because there were no immediate problems concerning the cleanliness of the laboratory air, the air cleaning effectiveness of the washer would not be considered.

Thus, the project is limited to the determination of the air washer thermal and flow characteristics. Which works on evaporative cooling system and perform the tasks

1. Cooling and humidification

2. Dehumidification

3. increasing purity of air by:

a. Removing dust particulates

b. Removing toxic/ harmful particulates

4.2 Working principle

In the air washer, the mean temperature of water droplets in contact with air decides the direction of heat and mass transfer. As a consequence of the 2" law, the heat transfer between air and water droplets will be in the direction of decreasing temperature gradient. Similarly, the mass transfer will he in the direction of decreasing vapor pressure gradient. Here some situations are explained.

a) Cooling and dehumidification:

Since the exit enthalpy of air is less than its inlet value, from energy balance it can be shown that there is a transfer of total energy from air to water. Hence to continue the process, water has to be externally cooled. Here both latent and sensible heat transfers are from air to water. This is shown by Process O-A in Fig.

[Dew-point temperature: If unsaturated moist air is cooled at constant pressure, then the temperature at which the moisture in the air begins to condense is known as dew point temperature (DPT) of air.

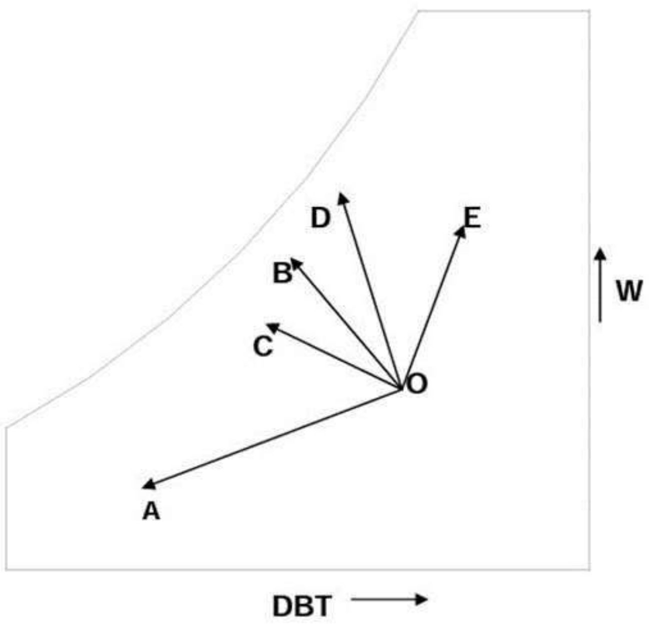
b) Adiabatic saturation:

Here the sensible heat transfer from air to water is exactly equal to latent heat transfer from water to air. Hence, no external cooling or heating of water is required. That is this is a case of pure water recirculation. This is shown process O-B in figure.

This is the process that takes place in a perfectly insulated evaporative cooler. [WBT- wet bulb temperature is defined as that temperature at which water, by evaporating into air, can bring the air to saturation at the same temperature adiabatically.]

c) Cooling and humidification:

Here the sensible heat transfer is from air to water and latent heat transfer is from water to air, but the total heat transfer is from air to water, hence, water has to be cooled externally. This is shown by Process 0-C in Fig.



d) Cooling and humidification:

Here the sensible heat transfer is from air to water and latent heat transfer is from water to air, but the total heat transfer is from water to air, hence, water has to be heated externally. This is shown by Process O-D in Fig. This is the process that takes place in a cooling tower.

The air stream extracts heat from the hot water coming from the condenser, and the cooled water is sent back to the condenser.

[Dry bulb temperature (DBT) is the temperature of the mist air as measured by a standard thermometer or other temperature measuring instruments.

e) Heating and humidification:

Here both sensible and latent heat transfers are from water to air, hence, water has to be heated externally. This is shown by Process O-E in Fig. Thus, it can be seen that an air washer works as a year-round air conditioning system. Though air washer is a and extremely useful simple device, it is not commonly used for comfort air conditioning applications due to concerns about health resulting from bacterial or fungal growth on the wetted surfaces. However, it can be used in industrial applications.

4.2.1 Advantages over VCR refrigeration system

1) Introduces the fresh air. Do not circulate the air.

2) Refrigerant is not required.

3) Compressor is eliminated which consumes much power. Around 90% less operating cost.

4) Installation is easy.

5) Full ventilation exhausts odors and germs. Increased cooling capacity as outside temperature rises.

4.2.2 Evaporating cooling system using air washer

Evaporative cooling has been in use for many centuries in countries such as India for cooling water and for providing thermal comfort in hot and dry regions. This system is based on the principle that when moist but unsaturated air conies in contact with a wetted surface whose temperature is higher than the dew point temperature of air, some water from the wetted surface evaporates into air. The latent heat of evaporation is taken from water, air or both of them. In this process, the air loses sensible heat but gains latent heat due transfer of water vapor. Thus the air gets cooled and humidified. The cooled and humidified air can be used for providing thermal comfort.

Classification of evaporative cooling systems:

1. Direct evaporation process

2. Indirect evaporation process

3. A combination or multi-stage systems

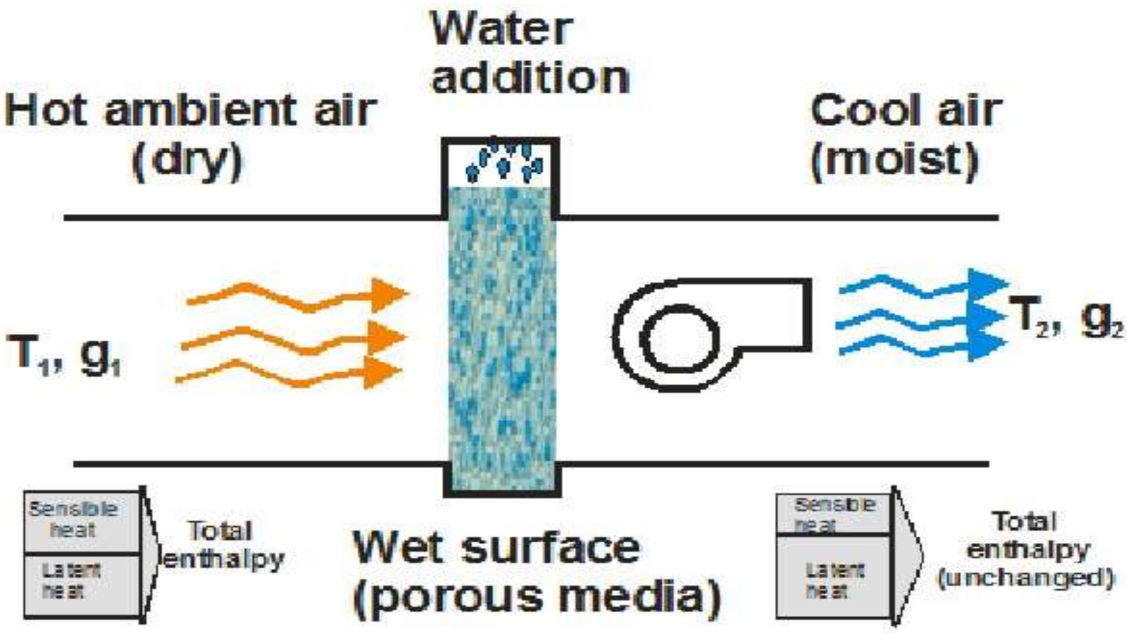
1. Direct evaporation process:

In direct evaporative cooling, the process or conditioned air comes in direct contact with the wetted surface, and gets cooled and humidified. Figure shows the schematic of an elementary direct, evaporative cooling system and the process on a psychrometric chart. As shown in the figure, hot and dry outdoor air is first filtered and then is brought in contact with the wetted surface or spray of water droplets in the air washer.

The air gets cooled and dehumidified due to simultaneous transfer of sensible and latent heats between Or and water (process o-s). The cooled and humidified air is supplied to the conditioned space, where it extracts the sensible and latent heat from the conditioned space (process s-i).

Finally, the air is exhausted at state in an ideal case when the air washer is perfectly insulated and an infinite amount of contact area is available between air and the wetted surface, then the cooling and humidification process follows the constant wet bulb temperature line and the temperature at the exit of the air washer is equal to the wet bulb temperature of the entering air (t), i.e., the process becomes an adiabatic saturation process.

However, in an actual system the temperature at the exit of the air washer will be higher than the inlet wet bulb temperature due to heat leaks from the surroundings and also due to finite contact area.



2.Indirect evaporation process:

Figure shows the schematic of a basic, indirect evaporative cooling system and the process on a psychrometric chart. As shown in the figure, in an indirect evaporative cooling process, two streams of air - primary and secondary are used. The primary air stream becomes cooled and humidified by coming in direct contact with the wetted surface (0-0'), while the secondary stream which is used as supply air to the conditioned space, decreases its temperature by exchanging only sensible heat with the cooled and humidified air stream (o-s).
Thus the moisture content of the supply air remains constant in an indirect evaporative cooling system, while its temperature drops. Obviously, everything else remaining constant, the temperature drop obtained in a direct evaporative cooling system is larger compared to that obtained in an indirect system, in addition the direct evaporative cooling system is also simpler and hence, relatively inexpensive.

However, since the moisture content of supply air remains constant in an indirect evaporation process, this may provide greater degree of comfort in regions with higher humidity ratio. In modern day indirect evaporative coolers, the conditioned air flows through tubes or plates made of non-corroding plastic materials such as polystyrene (PS) or polyvinyl chloride (PVC). On the outside of the plastic tubes or plates thin Film of water is maintained. Water from the liquid film on the outside of the tubes or plates evaporates into the air blowing over it (primary air) and cools the conditioned air flowing through the tubes or plates sensibly. Even though the plastic materials used in these coolers have low thermal conductivity, the high external heat transfer coefficient due to evaporation of water more than makes up for this.

3. Multi stage systems:

Several modifications are possible which improve efficiency of the evaporative cooling systems significantly. One simple improvement is to sensibly cool the outdoor air before sending it to the evaporative cooler by exchanging heat with the exhaust air from the conditioned space. This is possible since the temperature of the outdoor air will be much higher than the exhaust air.

It is also possible to mix outdoor and return air in some proportion so that the temperature at the inlet to the evaporative cooler can be reduced, thereby improving the performance. Several other schemes of increasing complexity have been suggested to get the maximum possible benefit from the evaporative cooling systems. For example, one can use multistage evaporative cooling systems and obtain supply air temperatures lower than the wet bulb temperature of the outdoor air. Thus multistage systems can be used even in locations where the humidity levels are high.

Figure shows a typical two-stage evaporative cooling system and the process on a psychrometric chart. As shown in the figure, in the first stage the primary air cooled and humidified (o -o') due to direct contact with a wet surface cools the secondary air sensibly (o -1) in a heat exchanger. In the second stage, the secondary air stream is further cooled by a direct evaporation process (1-2). Thus in an ideal case, the final exit temperature of the supply air (t,) is several degrees lower than the wet bulb temperature of the inlet air to the system (t).

4.3 Advantages and disadvantages of evaporating cooling systems:

Compared to the conventional refrigeration based air conditioning systems, the evaporative cooling systems offer the following advantages:

1. Lower equipment and installation costs.
2. Substantially lower operating and power costs. Energy savings can be as high as 75%.
3. Ease of fabrication and installation.
4. Lower maintenance costs.
5. Ensures very good ventilation due to the large air flow rates involved, hence, are very good especially in 100 % outdoor air applications.
6. Better air distribution in the conditioned space due to higher flow rates.
7. The fans/blowers create positive pressures in the conditioned space, so that infiltration of outside air is prevented.
8. Very environment friendly as no harmful chemicals are used.

Compared to the conventional systems, the evaporative cooling systems suffer from the following disadvantages:

1. The moisture level in the conditioned space could be higher, hence, direct evaporative coolers are not good when low humidity levels in the conditioned space is required. However, the indirect evaporative cooler can be used without increasing humidity
2. Since the required air flow rates are much larger, this may create draft and/or high noise levels in the conditioned space
3. Precise control of temperature and humidity in the conditioned space is not possible
4. May lead to health problems due to micro-organisms if the water used is not clean or the wetted surfaces are not maintained properly.

4.4 Application of air washer

1. Comfort conditioning suitable for malls, hotels, garment units, engineering units, industrial units etc.
2. Industrial ventilation cooling. Pre cooling.
3. compressor and gas turbines.
4. Hybrid air conditioners. 100% fresh air application.
5. Dust removal application.

4.5 Components of air washer

Air washer assembly consists of many important pans. It requires blower to draw the air in and out the chamber. An insulated water tank for storage of water. Spray drain for providing tine droplets of water. Different types of equipment are also used for carrying out the performance. Different components of air washer are as below:

1.Water tank

2.Blower

3.Spraying drain

4.Pump

5.Pipes and fittings

6.Chamber

7.Motor

8.Regulator

9.Filter

10.Pressure vessel

All the components are explained briefly below.

4.5.1 Water tank:

Water tank is located below the air washer. It is connected to the water pipe from suitable source for continuous supply of the water. The central air washer needs larger quantity of the water, which increases as the number of room to be cooled increases. For proper performance of the air washer one has to ensure the abundant supply of the continuously. The water in tank can be ordinary water or chilled water. Usually ordinary water is used.

In this experiment setup we used joint water tank so that temperature of water remains constant for a while. The required amount of water is supplied to the air washer continuously.

Specifications:

Breath: 17

Length: 18

Height: 8

Material: GI sheet 24 gauge

4.5.2 Blower

Blower is used to draw the air out the chamber so that supply of conditioned air is possible. For carrying out the performance analysis and find out the effect of air flow rate on process, speed of the fan changed through the regulator.

Specifications:

Diameter: 12

Power: Driven by shaft connected with 1400 rpm motor, AC motor Material:

plastic

4.5.3 Pump

Pump is required for supplying water from tank to the spray drain with pressure. Capacity of pump should be such that it can pump the water from the tank to the desire height without pressure loss. Location of the pump is also important as per the performance aspects. The height where the pump is located should be such that it would provide positive head. Many types of pumps can be used according the application. Types of pumps vary according to the flow rate of water required and cooling capacity. For high capacity like large room and high flow rate of water, centrifugal pump is used.

In our experiment we used a small centrifugal pump as the flow rate and capacity of setup is small. The specifications of the pumps are as below:

• Volts:24 V AC

• Current: 1.2 A

• Open flow: 1.5LPM

• Suction height: 2 m

• Inlet pressure: 30 PSI

• Working pressure: 74-90 PSI

4.5.4 Pipes and fittings

Connections from water tank to pump and from pump to spray drain are made with help of plastic pipes and joint. For desirable result of experiment make sure that there is no leakage in connection so that no loss in flow rate and in pressure. For different types of arrangement of setup different types of joints are used such as T joints, right angle joint (elbow) etc.

Diameter of the pipe is also important factor because the flow rate of water is depended on diameter of pipes. For high flow rates, diameter of the pipes should be large. We used the purifier pipes and joints for the experiment setup. Connections are made from water tank to centrifugal pump and then from pump to spray drain provided in chamber via plastic pipes and joints.

4.5.5 Chamber:

It is a box made of GI sheet in which the process takes place. The dimensions of the chamber vary according to the application. It should be such that it can accommodate the fan for drawing air. Make sure that all air passes through the chamber without leakage. It should also provide the provision for the accommodation of the nozzles. For water exit it should also provide provision at bottom of chamber so that water can be collected and its temperature can be measured. The main requirement of chamber is to provide leak proof passages so that desirable results can be achieved.

Specifications:

Breadth: 17"

Length: 20"

Height: 19"

4.5.6 Blower Casing

Made of GI sheet with circular diameter of 13.5 and 5 rectangular casing. Blower casing is used to maintain static pressure higher than the normal fan.

4.5.7 Motor

Motor used in this project is single blower motor which is used to drive both blower and centrifugal pump.

Specifications:

RPM: 1400

Power: 105W

Voltage:220V/50H

4.5.8 Filter

Filter is used for the purification purpose of the air washer. Many types of filters are used in specific air washers, like cellulose pads, nylon filter etc. But in this model nylon filter is used which is fixed in a panel frame.

4.6 Fabrication of Air Washer

We have discussed the different parts of the air washer assembly required in previous articles. From all the parts of the air washer most are standard equipment available in the market. Fan with the regulator, centrifugal pump with adapter, pipes and fittings are standard parts which is easily available. Only chamber, blower casing, tank and the spray drain with husk are fabricated according to the requirement. The fabrication of each portion is explained briefly below.

Water Tank:

Water tank is made up of GI sheet, which is snipped of from whole length GI sheet measurements are shown in figure. Riveting is done to attach the parts.

Casing:

Casing or body is also made up of GI sheet which are joint by riveting and bolts. In front portion there is a rectangular hole of 8 x 6 for the outlet of the air. In back casing there is filler used which is fixed in a plane frame.

Blower casing:

Blower casing is vital part of the model because it generates high static pressure air output it works on centrifugal action of blower it gives the direction for air output. Fu y of air. Outlet of blower casing er ducts can be installed for supply is 8"X6" dimension. Inner radius is 13.5". When the body of air washer has been fabricated, blower is installed in the blower casing, below which motor is under-mounted in which centrifugal pump is attached. In spray drain husk is attached for increasing the surface area of the water droplet in casing.

4.7 Experimentation

Now the experiment setup is ready for the performance. But before beginning the experiment setup should test to check whether it works according to the specification. Some precautions are made for getting desirable results.

4.7 Testing

4.7.1 Internal part of the washer:

✓ Spraying drain and husk should be centered in the chamber.

✓ Check the pipe connection for the leakage.

4.7.2 Hydraulic network:

✓ Check if the pump is duly installed. Check also if nuts and bolts of flanges are duly set.

✓ Feed the water tank and inspect for dirt build-up from assembly operations.

✓ If there is dirt, drain the tank and re-feed it.

✓ Before actuating the pump, check if rotation is correct.

✓ Operate the system and eliminate leaks.

4.7.3 External part of the washer:

✓ Check seals and access doors for perfect seating to prevent leaks.

✓ Actuate the fan (closed valve) and check if rotation direction is correct.

4.7.4 Washer starts up:

✓ The water circulation system must be the first one to be operated.

✓ The system must operate at full pressure to deliver spraying. Check all nozzles for normal operation.

✓ Make sure all access doors, passageways, ducts and other openings are closed, locked and bolted.

✓ Check the fan and regulator.

4.7.5 Instruction on how to stop the washer:

✓ First turn off the fan.

✓ After fan, disconnect the hydraulic network.

4.7.6 Precautions:

✓ Condition of pump and fan.

✓ Make sure there are no loose bolts in the whole set.

✓ Check the pipe joints for leakage.

After all these steps experiment setup is ready for use. Now in experiment we determine the effect of water flow rate and air flow rate on the cooling effect.

So we take the reading for two different water flow rates and air flow rate with help of the fan regulator.

4.7.7 Experiment procedure:

✓ First check the all connection and electric supply. ✓ Place the wet-bulb thermometer on the outlet of air washer ✓ Now measure the ambient temperature.

✓ Keep the inlet open and measure the water temperature in water tank ✓ Now measure the flow rate at still condition.

✓ Start the fan at full speed and turn on the pump, which supply the water from the water tank. Water from pump is supplied to the nozzles and line spray is produced in the chamber. ✓ Now measure the air velocity at exit portion with the help of the anemometer.

✓ Measure the exit air temperature.

✓ Now change the speed of the fan with help of regulator to minimum and take all the readings as mentioned above.

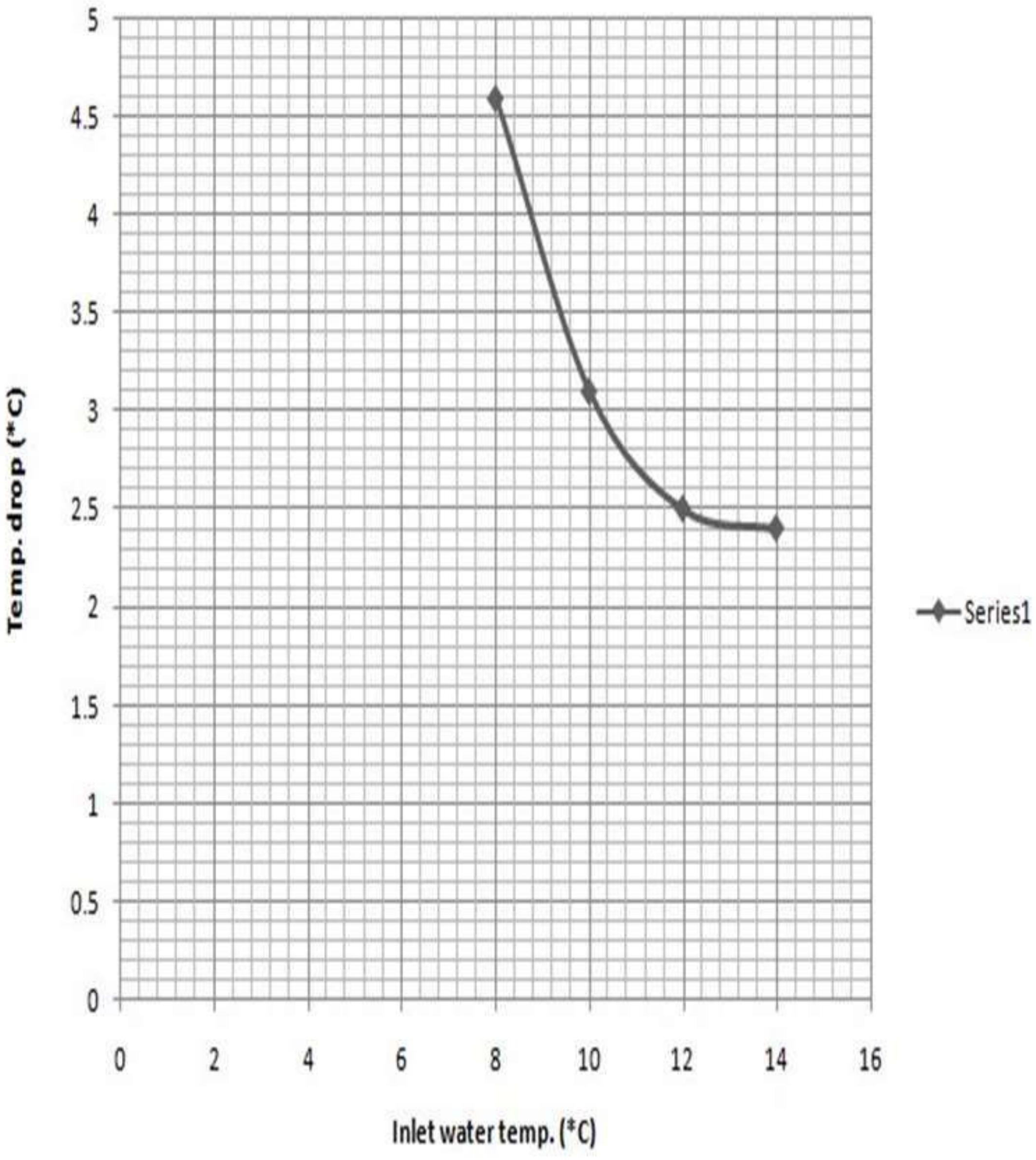
✓ Change the water temperature to 10*, 12*, 14* C and repeat all the procedure and note down the readings.

✓ After completion of the experiment turn of the fan and the pump.

47.8 Performance Curves:

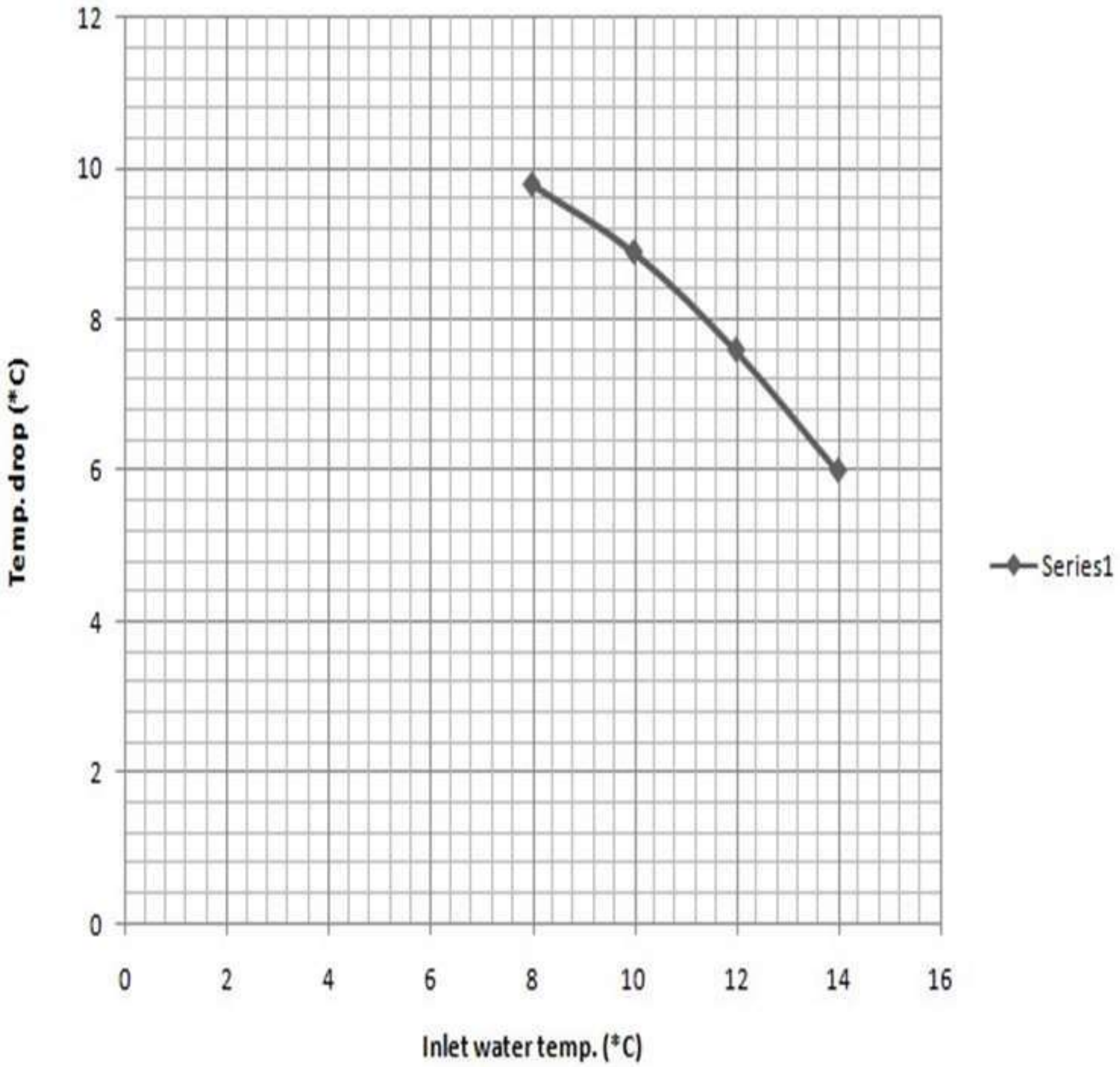
Water flowrate = 0.0000125 cubic meter/sec.

Air velocity = 6m/s.



Water flowrate = 0.000025 cubic meter/sec

Air velocity = 6m/s



Temp. drop (*C)
0
2
4
6
8
10
12
0
2
4
6
8
10
12
14
16
Inlet water temp. (*C)
Series1

4.8 Advantages and disadvantages of evaporating cooling system Air Washer:

Compared to the conventional refrigeration based air conditioning systems, the evaporative cooling systems offer the following advantages:

1. Lower equipment and installation costs.
2. Substantially lower operating and power costs. Energy savings can be as high as 75%.
3. Ease of fabrication and installation.
4. Lower maintenance costs.
5. Ensures very good ventilation due to the large air flow rates involved, hence, are very good especially in 100 % outdoor air applications.
6. Better air distribution in the conditioned space due to higher flow rates.
7. The fans/blowers create positive pressures in the conditioned space, so that infiltration of outside air is prevented.
8. Very environment friendly as no harmful chemicals are used.

Compared to the conventional systems, the evaporative cooling systems suffer from the following disadvantages:

1. The moisture level in the conditioned space could be higher, hence, direct evaporative coolers are not good when low humidity levels in the conditioned space is required. However, the indirect evaporative cooler can be used without increasing humidity
2. Since the required air flow rates are much larger, this may create draft and/or high noise levels in the conditioned space
3. Precise control of temperature and humidity in the conditioned space is not possible.
4. May lead to health problems due to micro-organisms if the water used is not clean or the wetted surfaces are not maintained properly.

Future Scopes

In future if improvement is done the same model of this project, following suggestions are established to improve the model:

- Auto controlling of blower and pump according to the requirements.
- Thermocouple can be included in the model.
- Separate control unit can be installed for humidification and dehumidification.
- Spraying of water mechanism can be improved.

4.9 Cost Estimation

S.NO	Item	Cost(INR)
1	Blower	100
2	Motor + pump	1000
3	GI sheets, nut-bolts,rivets	2500
4	Pressure vessel	150
5	Pipe and joints	50
6	Husk	15
7	Heating element	200
8	Extra misc	150
	Total	4165

4.10 Calculation:

Estimation of airflow rate for an air washer in evaporative cooling sysetm:

- Assume temperatures before and after of both the dry bulb and wet bulb temperature.

Before cooling :(existing)

Dry bulb - 106 F

Wet bulb – 89 F

After cooling :(to be obtained)

Dry bulb - 75 F

Wet bulb - 55 F **Air flow:**

Q= CFM x 0.69 x ΔW (latent heat constant=0.69)

Q=?

CFM=?

ΔW(wet bulb difference)

12000=CFM x 0.69 x ΔW

12000=CFM x 0.69 x (89-51)

12000=CFM x 0.69 x 34

CFM=511.72

Q= CFM x 0.69 x ΔW

Q= 511.72 x 0.69 x 34

Q= 12004.95 Kg **Water flow:**

Q=M x CP x ΔT

ΔT(dry bulb difference)

CP=1

M=1

Q= 1 x 1 x (106-75)

Q= 31 KJ

CHAPTER 5

Conclusion

From the graph we can conclude that

- As the water flow rate increases, the cooling effect increases as temperature drop increases.
- As the velocity of air decreases, mass flow rate of air decreases which increases the cooling effect.

➢ For constant water flow rate it is advisable to keep air mass flow rate low.

➢ For constant air flow rate it is advisable to keep the water flow rate as high as possible.

➢ Also the cooling effect increases as the inlet water temperature decreases. Better results can be obtained by providing 100 % leak proof setup and improving, the performance of nozzle by producing more atomized water spray.

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