Review on Two Stage Evaporative Cooler

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***Abstract*— Evaporative cooling is eco-friendly and energy efficient technology. There are mainly two types of evaporative technology, in which direct and indirect evaporative cooling takes place. Where in direct evaporative cooling there is adiabatic humidification and for reduction in relative humidity by means of cooling of air in heat exchanger. In case of indirect evaporative cooling the water sprayed in the heat exchanger. Primary purpose is to cool the air from the atmosphere to secondary air in the desired heat exchanger channel. All this concepts are taken in concern for the easiness, zero pollution with the energy efficiency of the cooling technology. From domestic purpose up to large industrial applications this evaporative cooling technology has been regularly used on large scale. In this review paper we have tried to explain the present the experimental work and research on the direct and evaporative cooling technology on the basis of their design, modelling and application by the details of studies in the terms of various performance tests and optimisation taking concern of heat and optimisation taking concern of heat and mass transfer also.**

***Index Terms*—Evporative cooling, heat exchanger, zero pollution.**

I. INTRODUCTION

Evaporative cooling technology is the more sufficient and eco-friendly technology which are mainly depends on the two criteria i.e. decrease in humidity and increase in temperature of surrounding. Therefore, in the hot and dry tropical regions the evaporative cooling technology can be used for saving large amount of the energy with air cooling. There are two main evaporative cooling systems where in the direct evaporative cooling system uses a cellulose media with the water contact surface where air is passed through it at a uniform rate. But, in this process humidity increases which is not desirable. Whereas in the direct evaporative cooling system the primary air is cooled by the passive cooling without making the direct contact with the water media. Where in such a case the temperature is maintained lower by the contact with the heat exchanger surface or channels separated by the flow of water and air. In this air is sensibly cooled without affecting the humidity. In both the system air is maintained to lower temperature is the wet bulb temperature (WBT). To avoid the various effects of direct evaporative cooler and by considering the low efficiency of indirect evaporative cooler the combined system of both this system is called indirect direct two stage evaporative cooler, for improved performance of a whole equipment.

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II. EVAPORATIVE COOLING SYSTEMS

A. Direct evaporative system

In this direct evaporative cooler the air is exposed to water directly which allows it to cool and then air gets moist by losingits sensible heat to latent heat of vaporisation of water. With the heat and mass transfer phenomena in the process there is some sensible heat gain from the exhaust fan, which helps to perform isenthalpic cooling by means of achieving the constant wet bulb temperature (WBT). The main disadvantage of the direct evaporative cooler is that by means of increase in humidity the Legionella disease can occurs by the small droplets of some moist water through the air flow.

Advantages and Disadvantages:

Based on available information ofdirectevaporativecoolingsystemdifferentadvantagesandd isadvantagescanbe summarized as follows:

Advantages:

1.Evaporative coolers are economical and gives high effectiveness.
2. Applicable in domestic as well as industrial application in a wide scale.
3. No specialised or skilled workers are required.
4. Mostly applicable for rural regions.
5. Components are available in the local market.
6. Highly efficient evaporative cooling systems that can reduce energy consumption.
7. Its installation and operation is easy.
8. Itcanbeeasilymaintained in easy way.

Disadvantages:

1. In the dry and hot tropical region water resource is one of the critical issues.
2. Evaporativecooling pads requirea continuouswatersupply.
3. Mineral contained water may damage the evaporative cooling pads and its design from inside.
4.They are only suitable for dry and hot climates.
5. Relativehumidityincrease which may cause Legionella disease when coming in direct exposure to human.

B. Indirect evaporative system

In the indirect evaporative system cooling effect by means of water evaporation without making any direct contact with the air flow, but through the channel or media of a nonporous wall. In this process there is only heat transfer between the air

and water in a cooling tower. This system overcomes the drawback of humidity and Legionella in the air flow. But, this system may not be effective compared to direct evaporative system.

Advantage:
1. Indirectevaporative cooler are introducedbecause they are of low costand relatively less expensive to convectionalAC.

Limitations:
1. Power consumption is more and results less effective due to which it has found limitedapplications in industries.

C. Direct/Indirect or two stage evaporative system

To avoid the various effects of direct evaporative cooler and by considering the low efficiency of indirect evaporative cooler the combined system of both this system is called indirect direct two stage evaporative cooler, for improved performance of a whole equipment.

III. PRACTICAL STUDIES ON EVAPORATIVE AIR COOLERS

A. Study on direct evaporative cooler

Many researchers performed work on direct evaporative cooler(DEC) successfully. Dowdy and Karbash used cellulose media of surface area of $360m^2/m^3$ withthickness310 mm practically to calculate heat and mass transfer coefficients for evaporative cooling process and obtained efficiency from 88to93%[1]. El-Dessouky precooled the incoming air before cooler not using cooling tower. He used packing of structured natural fibre as evaporating media with various thickness for high effectiveness and flow of water and determined thateffectivenessvariedwith thickness of evaporating pad andflowrateofwater in cooler[2]. Camargo showed experimental of using rigid cellulose media with wetted surface area of $375m^2/m^3$ and derived effectiveness in terms of various factors like mass flowrate of air, heat transfer coefficient, wetted surface area and specific heat for predicting the performance of different evaporating materials and come to conclusionthattheeffectivenessisincreased whenDBT is more[3].

Table 3.1.1. Study on effect of various parameters of DEC

Sr. No.	Researcher	Objective	Outputs
1.	Dowdy and Karbash (1987)	Heatandmasstransfercoefficients, efficiency	Obtained efficiencyfrom 88to93%
2.	El-Dessouky (1996)	Effectiveness	Effectivenessvariedwith thickness of evaporating pad andflowrateofwater in cooler
3.	Camargo (2005)	Massflowrate of air,heattransfercoefficient,wettedsurfaceareaandspecificheat	Effectivenessisincreased whenDBT is more

B. Study on indirect evaporative cooler

Many researchers performed work on indirect evaporative cooler (IEC) successfully. Chen performed thermal calculations for tube and plate- type heat exchanger channel usingavailable airassecondaryair and foundCOP and capacity of performance is muchhigherwhenroomairis used assecondaryair [4].Peterson also developed modest indirect evaporative cooler to determine heat and mass transfer process occurring within IEC and theoretical performance. His practical work stated single algebraic equation that can be solved in less iterations to calculate effectiveness of equipment [5]. Maheshwari compared the power consumption of indirect evaporative cooler with conventional AC. He found that effectiveness ofIECincreaseswiththedurationofmaximumcoolingcapacityandpowerrequirementofequipmentand facilitates reduction in same [6].

Table 3.2.1. Study on effect of various parameters of IEC

Sr. No.	Researcher	Objective	Outputs
1.	Chen (1991)	Thermalcalculations fortubeandplate-type heat exchanger channel, COP and capacity of performance	COP and capacity of performance is muchhigherwhenroomairis used assecondaryair
2.	Peterson (1993)	Determine heatandmasstransfer coefficients, theoretical performance	Statedsinglealgebraicequation thatcanbesolvedinlessiterations to calculate effectiveness of equipment
3.	Maheshwari (2001)	Powerconsumption, effectiveness	Effectiveness ofIECincreases withthe durationofmaximumcoolingcapacityandpowerrequirementofequipmentand facilitates reductioninsame

C. Study on direct/indirect or two stage evaporative cooler

El-Dessouky performed work on combination of DEC and IEC, a small evaporative cooler of structured packing material of high-density polythene with wetted surface area of $430m^2/m^3$ and come to conclusion thatefficiency islessthan directevaporative cooler butacombinationofbothmay decrease the temperatureofincomingairbelowits wet bulb temperature [7].Jain also developed two stage evaporative cooler to improve efficiency by using wooden shave as the evaporative material and returned air was successfully cooled used in heat exchanger channel with dry air and effectiveness variedfrom110%to 120% and attained favourable temperature and relative humidity conditions for storing of tomatoes less than14days [8]. Heidarinejad G . calculated performance of two stage evaporative cooler in various regions of Iran in which he usedplasticwetsurfaceheatexchanger channel of 18cmthickcellulose evaporative pad in the direct evaporative cooling and foundeffectivenessofindirect evaporative cooler unitvaried from56-60% andof two stage unit varied from107-110%and he come to conclusion that there is more water consumption than direct evaporative cooler and power demand of mechanical coolingsystems [9].

Table 3.3.1. Study on effect of various parameters of DEC/IEC or Two stage cooling unit

Sr. No.	Researcher	Objective	Outputs
1.	El-Dessouky (2004)	Efficiency,DBT	Efficiency islessthan directevaporative cooler
2.	Jain (2007)	Efficiency, effectiveness	Effectiveness varied from110%to 120%
3.	Heidarinejad G (2009)	Performance, effectiveness	EffectivenessofIEC unitvaried from56-60% andof two stage unit varied from107-110%.

IV. Conclusion

Fromthe whole review paper above we come to conclusion:
1. Due to various constraints like energy depletion and pollution evaporative cooling technology can be more useful.
2. Difference between DBT and WBT determines the effectiveness of evaporative coolers.
3. Evaporative coolingcanreduceprimary air temperatureto theroom considerably.
4.It is low costand energyefficient.
5. PrecoolingofwatercouldfacilitateDEC to lower its WBT.
6. Different factors like evaporative pad material and thickness,airvelocity,watercirculationfactors arefoundtoaffecttheeffectiveness ofevaporativecoolers.
7. More work to study the various parameterson theevaporativecoolerperformancefor varying air flow.
8. Pad thickness should be considered of prime importance for balancing the evaporation rate and pressure drop.
9. Study show that that excessive water flow does not increases effectiveness of cooling so the energy consumption should be given of prime importance.
10. Forhotandhumidregions two stage coolers areused for energy saving rather than conventional AC.

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