A REVIEW ON MULTI-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 namely direct evaporative cooler and indirect evaporative cooler. In direct evaporative cooling there is adiabatic humidification and reduction in relative humidity takes place by resources of cooling of air in heat exchanger. And indirect evaporative cooling the water sprayed in the heat exchanger. Primary purpose evaporative cooler is to cool the air from the atmosphere and further cool the 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. This evaporative cooling technology has been regularly used on large scale for domestic purpose as well as large industrial applications.

Keyword: Evaporative cooling, Direct / Indirect cooler, Effectiveness, Dew point, Dry bulb temperature.

I. INTRODCTION

In present time, great attention is paid toward energy saving, environment and energy efficiency. Production of energy adversely affects the environment and meanwhile increases greenhouse gas emissions. Despite this, there is increases global energy consumption from year to year. That is why the question of the development of new, cleaner and more efficient often technologies have been raised acutely in recent years. A large part of the world's energy is consumed by ventilation and air-conditioning. Practically in each modern building ventilation and air-conditioning systems are installed. Despite this, many of the old buildings where possible, are equipped with modern ventilation systems. Many of building facilities, such as hospitals and industrial buildings, have specific requirements for ventilation and air conditioning systems. One of the most energy-intensive processes in the ventilation and air-conditioning is the process of cooling. Evaporative cooling is the process by which the temperature of a substance is reduced due to the cooling effect from the evaporation of water. Evaporative cooling occurs when air, that is not too humid, passes over a wet surface; the faster the rate of evaporation the greater the cooling [1]. Generally, an evaporative cooling structure is made of a porous material that is fed with water. Hot dry air is drawn over the material. The water evaporates into the air raising its humidity and at the same time reducing the temperature of the air [2].The fundamental governing process of evaporative cooling is heat and mass transfer due to the evaporation of water. This process is based on the conversion of sensible heat into latent heat. Sensible heat is heat associated with a change in temperature. While changes in sensible heat affect temperature, it does not change the physical state of water. Conversely, latent heat transfer only changes the physical state of a substance by evaporation or condensation [3].As water evaporates, it changes from liquid to vapour. This change of phase requires latent heat to be absorbed from the surrounding air and the remaining liquid water. As a result, the air temperature decreases and the relative humidity increase. The maximum cooling that can be achieved is a reduction in air temperature to the wet-bulb temperature (WBT) at which point the air would be completely saturated [1,4]. This system is the oldest and the simplest type of evaporative cooling in which the outdoor air is brought into direct contact with water, i.e. cooling the air by converting sensible heat to latent heat. Ingenious techniques were used by ancient civilizations some of it by using earthenware jar water contained, wetted pads/canvas located in the passages of the air [5].The most commonly used direct evaporative coolers are essentially metal cubes or plastic boxes with large flat vertical air filters, called ―pads, in their walls. Consisting of wet table porous material, the pads are kept moist by the water dripped continuously onto their upper edges. The process air is drawn by motorized fans within the coolers. After being cooled and humidified in the channels between the pads, the air leaves the cooler as ―washed air‖ for cooling use. Many coolers use two-speed or three-speed fans, so the users can modulate the leaving air states as needed.[6]Fig. 1 is the schematic diagram of a drip-type DEC. Water is sprayed at the top edges of the pads and distributed further by gravity and capillarity. The falling water is recalculated from the water basin by the water pump. In DEC, the process air contacts directly with the sprayed water and hence is cooled and humidified simultaneously by the evaporation of water.[7] This paper aims to review direct evaporative cooling technologies that could potentially provide sufficient cooling comfort, reduce environmental impact and lower energy consumption in buildings. Experimental and theoretical research works on feasibility studies, performance test and optimization as well as heat and mass transfer analysis are reviewed in detail.

This paper consists of several parts which are as follow. The first part includes the introduction; part 2 describe the basic principal of evaporative cooler , part 3 classify the evaporative cooler , part 4 describes the advantage and disadvantage , part 5 mention the methodology used in evaporative cooler , and the last section concludes.

II. BASIC PRINCIPLES

Evaporative coolers lower the temperature of air using the principle of evaporative cooling of different typical air conditioning systems which relate vapor-compression refrigeration or absorption refrigerator. Evaporative cooling is the addition of water vapor into air, which causes a lowering of the temperature of the air. The energy required to evaporate the water in use from the air into the form of sensible heat, which affect the temperature of the air, and converted into latent heat, the energy present in the water vapor component of the air, at the same time as the air remains at a constant enthalpy value. This change of sensible heat to latent heat is known as an adiabatic process because it occurs at a constant enthalpy value. Evaporative cooling therefore causes a drop in the temperature of air proportional to the sensible heat drop and an increase in humidity proportional to the latent heat gain. Evaporative cooling can be visualize using a psychometric chart by finding the initial air condition and moving along a line of constant enthalpy toward a state of higher humidity.

Vapor-compression refrigeration use evaporative cooling, but the evaporated vapor inside a sealed system, and is then compressed ready to evaporate again, using energy to do so. Simple evaporative coolers water is evaporated into the environment, and not recovered. In an interior space cooling unit, the evaporated water is introduced into the space along with the now-cooled air; in an evaporative tower the evaporated water is carried off in the air flow exhaust.

2.1 Evaporative Cooling with Psychometric Chart

According to Rusten [8] cooling through the evaporation of water is an ancient and effective way of cooling water. He further disclosed that this was the method been used by plant and animal to reduce their temperature Evaporative cooling would take place which are stated below

(1) Temperatures are high

(2) Humidity is Low

(3) Water can be spared for its use

(4) Air movement is available (from wind to electric fan)

the change of liquid stage to vapour requires the addition of energy or heat. The energy that is added to water to change it to vapour comes from the environment, thus making the environment cooler. Therefore, the use of the psychometric chart is of great importance in order to discover whether evaporative cooling has taken place. Air conditions can be quickly characterized by using a special graph called a psychometric chart. Properties on the chart include dry-bulb and wet-bulb temperatures, relative humidity, humidity ratio, specific volume, dew point temperature, and enthalpy Beiler [8]. When considering water evaporating into air, the wet-bulb temperature, as compared to the air's dry-bulb temperature is a measure of the potential for evaporative cooling.The greater the difference between the two temperatures, the greater the evaporative cooling effect. When the temperatures are the same, no net evaporation of water in air occurs, thus there is no cooling effect (Wikipedia.com). Therefore for optimum cooling efficiency using the evaporative cooling technique temperature and the relative humidity measurement is needed to be taken and the psychometric chart defines these variables at various stages.

III. TYPES OF EVAPORATIVE COOLING SYSTEMS

The evaporative cooling can be achieved by direct, indirect systems, or combining these two types in various stages.

3.1 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 losing its sensible heat to latent heat of vaporization of water. With the heat and mass transfer phenomena in the process there are 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 which can occurs by the small droplets of some moist water through the air flow.

3.1.1 Heat and mass Transfer Process in a Direct Evaporative Cooler

The common direct evaporative coolers are essentially cubical metal or plastic boxes with large flat vertical air filters, called ‘‘pads”, in their walls. Consisting of very wet table porous material, they are kept humid by water drip continuously against their upper edges. Mechanical centrifugal fans within the boxes draw in air through pads, which both cools and humidifies the air. The discharged air from coolers often named as ‘‘washed air” is used for cooling use. Many cooler have two or three fan speeds, thus user can modulate outputs as needed. Fig.1 a shows the inner configuration of a drip-type direct evaporative cooler with three pads in the side walls and the last side used as washed air outlet. Water is spread to wet the pad material and recycled from the sink driven by a pump. The water spread onto the top edges of pad is distributed further by gravity and capillarity. The effectiveness of a drip-type cooler depends largely upon pads that combine maximum clean wet surface area with minimum air flow resistance. That requires materials having either good ‘‘wick” individuality or surfaces that spread water rapidly by capillary action and through which air easily passes. Neglecting heat flux transferred from surroundings, air is cooled and humidified with constant enthalpy, and i.e. air loses a certain amount of sensible heat as well as gains an equal amount of latent heat of water evaporation. Water temperature in the basin will almost be a certain value that is slightly higher than the wet-bulb temperature of inlet air during a stable operation period of the cooler. Thus, the air process in the direct evaporative cooler is different from that of cooling tower in some level. The following theoretical analysis will focus on the heat and mass transfer of a direct evaporative cooler in which the air flow channels are formed by the alternate layers of two kinds of wet table papers with different wave angles. The simplified sketch of a direct evaporative cooler is shown in Fig.1 shows the configuration of a pad module, x-axis donates air flow direction; z-axis donates the water sprinkle direction. To simplify the heat and mass transfer analysis, the following assumptions are employed: the pad material is wetted uniformly and fully; the convective heat transfer coefficient (hc)and mass transfer coefficient (hm) of moisture air on the surface of water film are constant the thermal properties of air and water are constant water–air interface temperature is assumed to be uniform and constant; the heat flux transferred from the surroundings is neglected; air near the water–air interface is saturated, its temperature is assumed to be that of sprinkled water air temperature changes only in flow direction denoted by x [9].

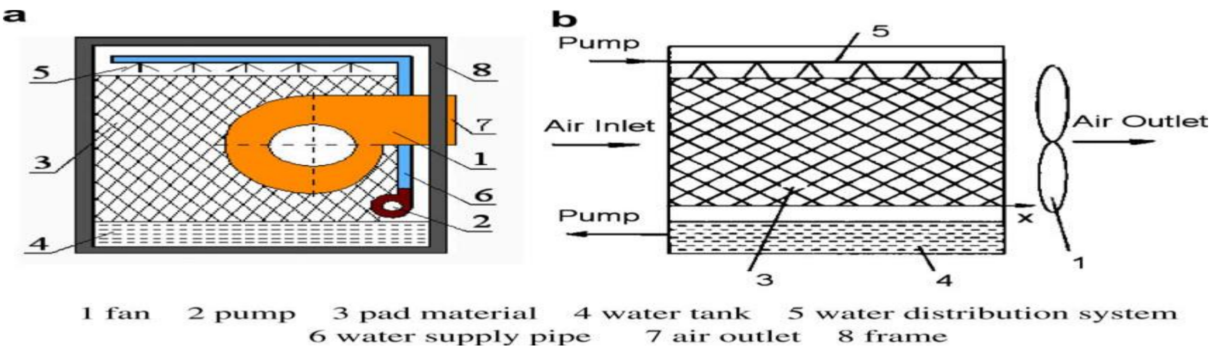

Fig.1 Sketches of the inner configuration (a) and the working principle (b) of a drip-type direct evaporative cooler.

3.1.2 Numerical Investigation on the Heat and Mass Transfer in a Direct Evaporative cooler: Introduction

Evaporative cooling systems, for example water cooling towers, evaporative condensers, evaporative fluid coolers, air washers, and dehumidifying coils, are widely used in industry. Their key process is heat and moisture transfer between air and water. The use of evaporation of water in air conditioning is an old and well-known technology; however, its importance is again being recognized due to its characteristics of zero pollution, energy efficiency, simplicity and good indoor air quality. The evaporative air conditioning systems as well as direct evaporative cooler units have been used in many arid areas of the world such as southwestern United States, Australia, western Asia and northwestern China. Provided a general non-dimensional mathematical model for the description of all types of evaporative cooling devices in use today (water cooling towers, evaporative condensers, evaporative fluid coolers, air washers, etc.). The differential equations describing non-

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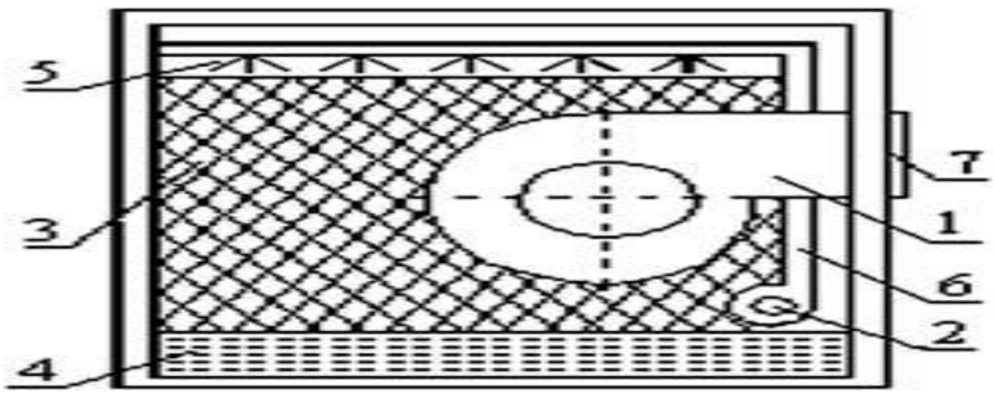
adiabatic evaporative processes are transformed to purely non-dimensional forms by the introduction of non-dimensional coordinates and parameters and by the substitution of the real air saturation curve by a linear air saturation line [10].

3.1.3 Numerical simulations of the heat and mass transfer process of the direct evaporative cooler

The most common direct evaporative coolers are essentially metal cubes or plastic boxes with large flat vertical air filters, called ‘‘pads”, in their walls. Consisting of very wet table porous material, they are kept moist by water dripped continuously onto their upper edges. Motorized centrifugal fans within the boxes draw in air through the pads, which both cools and humidifies the air. The discharged air from coolers, often referred to as ‘‘washed air”, is used for cooling. Many coolers have two or three fan speeds, so the user can modulate the output as needed. The inner configuration of a drip-type direct evaporative cooler consists of three pads in the side walls and the last side used as the washed air outlet. Water is sprinkled to wet the pad material and is recycled from the basin by a pump. The water sprinkled onto the top edges of the pads is distributed further by gravity and capillarity. The drip cooler effectiveness depends largely on the pads combining a maximum clean wet surface area with minimum air flow resistance. This requires materials having either good wicking characteristics or surfaces that spread water rapidly by capillary action in addition to allowing air to easily pass. If there is no heat transfer from the surroundings, the air is cooled and humidified with constant enthalpy; that is, the air loses a certain amount of sensible heat but gains an equal amount of latent heat of water vapor. The water temperature in the basin will be slightly higher than the wet-bulb temperature of the inlet air during a stable operation period of the cooler. Thus its operation state is different to that of the cooling tower to some extent. The following numerical simulation focuses on the heat and mass transfer of a direct evaporative cooler in which air flow channels are formed by the alternate layers of two kinds of wet table papers with different wave angles, as shown in Fig 2. The x-axis denotes the air flow direction, the y-axis denotes the width direction of the pad, and the z-axis denotes the water sprinkling direction [10].



1 fan 2 pump 3 pad material 4 water basin 5 water distribution system 6 water supply pipe 7 air outlet

Fig. 2. The inner configuration of a drip-type direct evaporative cooler

3.1.4 Mathematical models

Based on the characteristic of the evaporative cooler declared above, assumptions are made to establish a reasonable

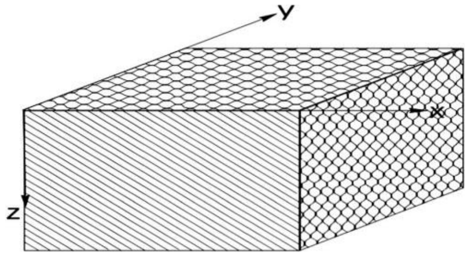


Fig.3 Air flow channels formed by the alternate layers of two kinds of Wet table papers with different wave angle

simplified mathematical model for the numerical simulation the direct evaporative coolers operating state is steady the pad material is simply and uniformly wetted by capillary action, and of course a good sprinkler is needed to distribute water uniformly onto the upper edges of the pads the water film on the pad surface is very thin, stable and uniform without much water dropping air temperature and humidity does not vary in the water sprinkling direction (usually it is the direction of gravity), thus air flow is simplified to be steady two-dimensional flow for the mass transfer between air and water, the water evaporation is treated as the mass source term of air flow, the related water evaporation latent heat is taken as the heat source of the energy equation, and the momentum caused by the evaporated water (vapor) is taken into account in the momentum equations, thus only a simplified governing equation set for air is developed; and the air thermal properties are constant[10]

3.1.5 Evaporative cooling pad: Evaporative cooling pads are currently the most effective and efficient systems for cooling boiler house. These systems drip water downward through a porous pad while air flows across the pad into the broiler house. New pads, or those in good condition, generally have high efficiencies (70 – 90%); and when sized, installed, and maintained properly, can provide more cooling effect than fogging without the risk of wetting the broiler house interior. Recalculating-type pads use a plumbing system including a sump and pump to recalculate the water through the pads. Fogging pads are a variation in which the pad is wetted by fogging nozzle spray instead of a Recalculating water delivery system. Pad and fan evaporative cooling systems can be very effective and are widely used in houses with more valuable chickens, such as breeders and layers. Since a static pressure drop across the pads is required, pad and fan systems cannot be used with natural wind (open curtain) ventilation and are mostly used in tunnel-ventilated poultry houses. Since pad and fan systems tend to be more expensive than fogging systems, meat bird producers have been slower to adopt them. Fogging-pad systems represent an intermediate option.

3.1.6 Pad selection: Selection of evaporative cooling pads should involve consideration of product effectiveness, useful life, and maintenance requirements in addition. The least expensive pad materials may not be very cost-effective, since they are generally less effective at cooling. The evaporative cooling efficiency is a good indicator of pad performance, since it represents the fraction of the potential cooling effect which the pad will provide. Evaporative cooling efficiencies of 80-90% are typical of well-designed cellulose pad systems in good condition.

3.1.7 Pad Size: Sizing of pad systems is based on preventing excessively high air velocities through the pad. High velocities can cause high static pressure drops and blow water off the pads both of which reduce system effectiveness.

3.1.8 Pad Placement: Placement of the pads depends on the ventilation system design, given that the pads serve as the hot weather air inlets. The tunnel ventilation inlet area should ideally be placed in the end wall farthest from the exhaust fans to avoid a dead-air space near this end wall. However, the large amount of pad area required and the large end wall access doors typically necessitate placing most, if not all pad material on the side walls. Place one-half the pad area in each side wall and directly across from each other.

3.1.9 Water Flow Rate: Water flow rate through the pads should be sufficient to flush away dust, salts, and minerals that could otherwise foul the pads. This flow rate will be several times the actual water evaporation rate from the pads. Specific recommendations of water flow rate and sump capacities provided by pad manufacturers should be followed. When pads are installed on sidewalls, a separate sump and pump should be used for each pad to avoid excessive pumping distances. Larger pipes and fittings are needed as the required flow rate (gpm) increases. For riser and feeder lines longer than 50 feet, pipe and fitting sizes should be increased to avoid excessive head loss or a larger pump will be needed. The same size pipe should be used from the outlet of the pump to the inlet of the distribution pipe.

3.2 INDIRECT EVAPORATIVE SYSTEM

Indirect evaporative coolers can be utilized to cool air or other fluid with wet surface heat exchangers. The surface of the cooling air passages is wetted by spray water (also named recirculation water), so that water film evaporates into the cooling air and decreases the temperature of the wetted surface. The primary air or other process fluid flows in the alternative passages and is cooled by indirect contact with the spray water film through the separating wall of the heat exchangers. Nowadays, energy availability is essential for everyday life and welfare all over the world. Therefore, population and growth is expected to involve a faster increase in energy consumption, despite the rise in fossil fuel prices. Taking this into account, many problems such as dependency on sources, increased cost or the environmental impact of energy use and transformation are to be faced. Thus, new legislation to ensure sustainable energy provision at an affordable price is needed [11]. The environmental impact associated to the use of energy from conventional fossil origin, the energetic and economic dependency on non-renewable sources, lead to the necessity of reducing the energy consumption, maintaining the current targets and necessities of each activity that require the use of energy. On the climatic conditions [12]. Moreover, due to the high number of users of the building sector, an improvement on the energy efficiency of the systems leads to an important decrement on the energy consumption, thus being this sector one of the most interesting fields to focus the activity to improve the energy efficiency. However, not only the economic savings have to be considered in the study of the improvements in energy efficiency, whose profitability is commonly uncertain, but also the reduction in the environmental impact or in the misused of natural resources implied [13]. Despite the fact that the priority of the new dispositions introduced for energy management, new devices and generators among others, is to reduce the energy consumption in buildings, they must ensure a proper comfort level and well being of their users [14]. Consequently, it should be considered the introduction of systems that permit condition the hydrothermal environment of the rooms, maintaining an adequate indoor air quality and thermal comfort, with low energy requirements, when providing energetic viable solutions to obtain a proper thermal environment in buildings In the case of indirect evaporative cooling, water evaporates in a secondary air stream which exchanges sensible heat with the primary one in a heat exchanger. In this way, the outdoor air stream is cooled when keeping into contact with the surface through which the heat exchange is produced, without modifying its absolute humidity; whereas at the other side of this surface the secondary air stream is being evaporative cooled. Thus, this process is called indirect and is mainly used in those applications where no humidity addition is allowed in the supply air, as well as no risks of pollution, as no mass exchange is permitted between the two air streams.

3.2.1 Indirect evaporative cooling system with tubular heat-exchanger: The first reference to this kind of system comes from 1908, from a patent of a German inventor called. Subsequently, models made of a window air cooler have been developed, which permitted obtaining outdoor air that passed inside a bank of fine horizontal tubes with the aid of a fan, while water was sprayed on the outer walls. More modern designs of these systems used plastic tubes that resisted corrosion better. The operation configuration of this kind of devices

3.2.2 Indirect evaporative cooling systems with a plate heat-exchanger: This is undoubtedly the most used indirect evaporative system. The first reference known to this system comes from 1934, and that design suggested two stages. In the first stage return air is cooled in two spray humidifiers (direct evaporative cooling). Afterwards, this air is used in a plate heat-exchanger to cool outdoor air which will be supplied into the cooled room. Humid air is thrown outdoors. One advantage of this system is that water does not take into contact with the exchange surface, thus not originating incrustations. However, these are really large devices, and heat-exchange between gas mediums requires great areas of transference, so they are not used.

3.2.3 Indirect evaporative cooling with Sub-wet bulb temp

A sub-wet bulb temperature indirect evaporative cooling process can be achieved by pre-cooling of the working air. This can be done by branching the working air from the product air, after it has been cooled. Therefore, the ultimate temperature for the cooling process will be the wet-bulb temperature of the pre-cooled working air and not that for the ambient air. This makes the main improvement in this process because it allows bringing the product air to temperatures lower than the ambient wet bulb temperature. The branching of the working air from the product air can be done in a single-stage regenerative arrangement or multi-stage arrangements. A detailed analysis of the thermal performance of sub-wet bulb temperature indirect evaporative cooling using a finite difference numerical model for single-stage counter-flow regenerative cooler as well as multi-stage coolers (with different flow directions: counter-flow, parallel-flow and combined parallel-regenerative) was published by the author [15].

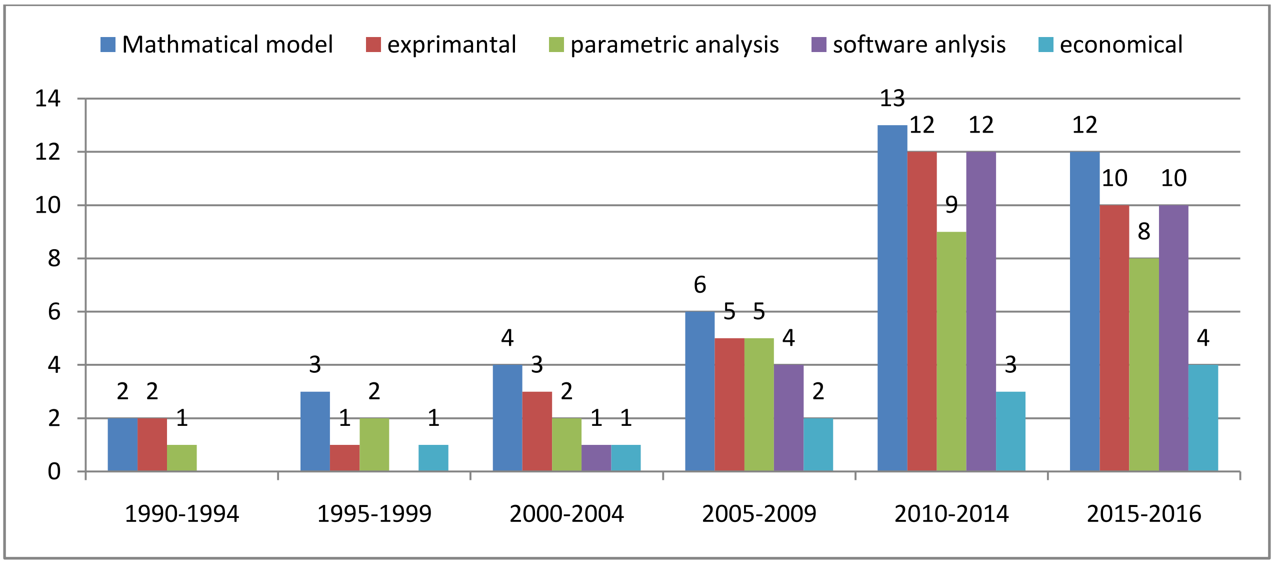
IV. ADVANTAGES AND DISADVANTAGES OF EVAPORATIVE COOLER

The main advantages of evaporative coolers are their low cost and high effectiveness, permitting a wide range of applications and versatility in the buildings, dwellings, commercial and industrial sectors. They can be specially applied in dry and hot climates as the minimum cooling temperature for the air depends on it's the wet bulb temperature. Evaporative air coolers which are used for air-conditioning in hot and dry climates, have considerably low energy consumption compared to refrigerated systems. Because they do not need any refrigerant, Evaporative air coolers have another important advantage over refrigerated systems which are associated with the ozone layer depletion problem.

Disadvantage is the water consumption associated to the operation of these systems, which is a scarce resource in dry and hot climates. However, the reduction in electric consumption implies compensation in the global amount of water consumed. This is due to the fact that conventional power plants with an average performance of 40% require removing the remaining 60% heat in a cooling tower. Thus, the electric energy used in conventional systems

V. TYPES OF METHODOLOGY USED IN THE WORLD

Study of performance of multi stage evaporative cooler (MSEC) and its studies were used on various way and its results were recorded for future work. In the last two decades, researchers work on the mathematical model, experimental studies, and parametric analysis. During last ten years most of the analysis was performed on computer software using MATLAB, CFD, and ANSYS In the resent five years research also used on coupled or integrated with MSEC to improve the performance of multi stage evaporative cooler. In this section pie diagram shows the methodology conducted by researches. The below data were obtained by studied of 88 research papers.



5.1 Mathematical model only: P.J.ERENS et al [16] modeling of indirect evaporative air coolers - The modeling of indirect evaporative air coolers is discussed and three calculation models are described. Sample calculations show that the optimum shape of the cooler unit would result in a primary to secondary air velocity ratio of about I .4, assuming that the primary and the secondary air mass flow rates are the same and that the same plate spacing are used on the primary and secondary sides. In conclusion it is found that the simplified model gives good results and is recommended for the evaluation of smaller systems and for initial design purposes while the more sophisticated methods should be used for more accurate performance prediction. Changhong Zhan et al [17] Numerical study of a M-cycle cross-flow heat exchanger for indirect evaporative cooling- In this paper, numerical analyses of the thermal performance of an indirect evaporative air cooler incorporating a M-cycle cross-flow heat exchanger has been carried out. The numerical model was established from solving the coupled governing equations for heat and mass transfer between the products and working air,

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using the finite-element method. The model was developed using the EES (Engineering Equation Solver) environment and validated by published experimental data. Correlation between the cooling (wet-bulb) effectiveness, system COP and a number of air flow/exchanger parameters was developed. It is found that lower channel air velocity, lower inlet air relative humidity, and higher working-to-product air ratio yielded higher cooling effectiveness. DEMIS PANDELIDIS et al [18] Performance study of counter-flow indirect evaporative air cooler **-**This paper numerically investigates the performance and heat and mass transfer processes that occur in counter-flow indirect evaporative air coolers. Different types of counter-flow air coolers were compared: a typical counter-flow unit, the same unit operating as a heat recovery exchanger, a regenerative unit and a novel modified exchanger.

5.2 Experimental Analysis only: Honghyun Cho et al [19] Performance of a showcase refrigeration system with multi-evaporator during on–off cycling and hot-gas bypass defrost- During the defrosting process, the temperature in the cabinet of a showcase becomes higher than the set point. This phenomenon is undesirable for foods or products stored. It is essential to develop an efficient defrosting method to prevent large temperature fluctuations. In the present study, the performance of the showcase refrigeration system with three evaporators was measured during on–off cycling and hot-gas bypass defrost. Based on the test results, the effects of off-period in the on–off cycling and EEV opening in the hot-gas bypass defrosting cycle on the performance of showcase system were analyzed. In addition, the operating characteristics of the hot gas bypass defrosting cycle were compared with those of the on–off cycling. The hot-gas bypass defrosting method showed higher refrigerating capacity and less temperature fluctuations than the on–off cycling under frosting/defrosting conditions even though it required more compressor power. Evyatar Erell et al [20] A Multi-Stage Down-Draft Evaporative Cool Tower for Semi-Enclosed Spaces- A multi-stage down-draft evaporative cool tower (DECT) was developed as an improvement to an existing single-stage design. The new tower incorporates a secondary air inlet, added to increase the cooling output and reduce the water consumption in a tower of given cross-section and primary inlet geometry. The secondary air, which may be drawn from the interior space being cooled, is cooled by evaporation in the lower section of the tower.

5.3 Parametric analysis: Modeling is very useful tool in order to predict the effect of the operating parameters like pad thickness, pad material, water flow rate and air flow rate on the thermal performance and heating/cooling capacity of multi-stage evaporative cooler systems. A number of computer modeling tools are commercially available. Computational Fluid Dynamics (CFD) is very popular among researchers for modeling and performance analysis of MSEC systems. CFD codes are prepared around the numerical algorithms that can deal with fluid flow problems. The partial differential equations governing airflow and heat transfer can be solved numerically in a discretized form with CFD. The effect of operating parameters i.e. pad thickness, pad material, water flow rate and air flow rate on the Some of the commercial CFD codes in use are FLUENT, CFX, STAR CD, FIDAP, ADINA, CFD2000, PHOENICS and others

VI. CONCLUSION

1. From the whole review paper above we come to conclusion. the multi stage evaporative cooler is a promising option from energy conservation point of view

2. Due to various constraints like energy depletion and pollution evaporative cooling technology can be more useful
3. Different factors like evaporative pad material and thickness, air velocity, water circulation factors
4. Pad thickness should be considered of prime importance for balancing the evaporation rate and pressure drop more work to study the various parameters on the evaporative cooler performance for varying air flow
5. Study show that that excessive water flow does not increases effectiveness of cooling so the energy consumption should be given of prime importance
6. Evaporative cooling can reduce primary air temperature to the room considerably
7. It is low cost and energy efficient
8. Difference between DBT and WBT determines the effectiveness of evaporative coolers.
9. Pre cooling of water could facilitate DEC to lower its WBT.
10. For hot and humid regions two stage coolers are used for energy saving rather than conventional AC

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