Enhanced Performance of Evaporation based Air Cooling – A Review

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Abstract - *In modern times our main focus is on energy savings and less use of fossil fuels. In our society conventional vapour compression air conditioning is dominant over evaporative cooling which produces harmful effect to our environment and consumes very high amount of energy, to overcome this we are focusing towards improving the efficiency of evaporative cooler which is environmental friendly and less energy consumptions. Evaporative cooling is purely based on evaporation of water as it have many applications such as HVAC, microclimate cooling, industrial cooling. Evaporative cooling can be classified into many categories such as air mediate v/s water mediate and direct evaporative cooling v/s indirect evaporative cooling. In this paper we discuss about history, current status, operational mode and the recent developments in evaporative cooler.*

***Key Words*:** Evaporative cooling, Desiccant and membrane based cooling Indirect & Direct evaporative cooling, Cooling of water using cooper tube.

1. INTRODUCTION

Evaporative cooling operates by utilizing natural phenomena where water and air are the working fluids. Evaporative cooling process is a commonly used for cooling towers, air washers, condensers, fluid cooling and to the places where several heat sources are present. If the air used for evaporating cooling is not too humid, the faster rate of evaporation results in greater rate in the cooling. When air passes wet surface then evaporating cooling occurs. The arrival of vapors compression based air conditioning system has limited the use of the direct evaporative cooling system for air conditioning. Vapor compression based air conditioner emits the ozone layer depletion gases, global warming potential gases that are a serious concern for our environment, additionally; it consumes more energy. Due to the harmful effect of VCRS system humans realized that use of evaporative cooling is better than Mechanical VCRS system. As evaporative cooling is a natural process and it does not harm our environment and it consumes less energy as compare to VCRS system. As we can see the use of evaporative cooling is increasing very rapidly, evaporative cooling have many application like in HVAC system, industrial cooling, microclimate cooling etc. The HVAC system installed in many companies to provide human comfort to their employees so that they can work effectively, and in survey it was found that around 50% of total energy is consumed by HVAC system only to provide human comfort [1]. And in the very hot climate conventional air conditioning system causes power cut due to the increase in loads. Microclimate cooling is another important application of evaporative cooling which focused to study on the astronaut life support system; however, it can also be achieved by liquid chilled circulating suit of astronaut. Evaporative cooling gives its best performance in arid region, whereas in mild humid or humid region cooling is not effective, its cooling efficiency depend on the wet bulb temperature of upcoming area, it also increases moisture content in the air which causes human discomfort and also provide rusting to the material, provide growth to the germs made from humidity of air, so to overcome this all problems researchers are working on this area so that evaporative cooling provides its best performance in humid area, provide human comfort and gives efficient cooling without increase in moisture content. It is seen that during the process of evaporative cooling water and air both gets cooled and air is used to cool the required space/environment and the use of cooled water is not taken, so we can also use the cooled water for various purposes that we will be doing in our studies.

2. TECHNOLOGIES IN EVAPORATIVE COOLING*:*

All evaporative cooling process involves at least a water stream and an air stream, which serves as either the cooling medium or the complimentary medium. The cooling medium is the fluid (water or air) that is first chilled because of water evaporation and then used to cool the object in contact with it and a complimentary medium is the fluid (water or air) that is required for water evaporation to take place but is not used to cool the object of interest directly.

2.1 DIRECT EVAPORATIVE COOLING (DEC):

In this air is act as cooling medium and water is act as complimentary medium. In DEC air comes in direct contact with water and provides heat (sensible heat) to the water which gets evaporated and mix with the air in the form of vapor by latent heat, which cause to increase in moisture content of air (cooling medium). In DEC, cooling of air limits to its wet bulb temperature and we cannot achieve temperature below it. As an example; below in fig.1 we can see that a honeycomb like structure material of cellulose is made in which water in sprayed continuously in uniform way and when the dry air comes in contact with water it gets cooled and humidify simultaneously and water circulated by the help of pump.

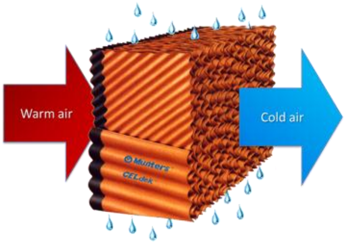

Fig.1 direct evaporative cooling [2]

A Ground Coupled Circuit (GCC) provides the necessary precooling Effects, enabling a DEC that cools the air even below its WBT. Simulation results revealed that the combination of GCC and DEC system could provide comfort condition whereas DEC alone cannot [3].

2.2 INDIRECT EVAPORATIVE COOLING:

In and IDEC there is two flow of air one is primary air which is used as cooling medium and another is secondary air which is used to cool the primary air. In IDEC the secondary air comes in direct contact with water and then the water evaporates and the cool as well as humidify simultaneously the secondary air which is now further used to cool the primary air which is not in direct contact with water as well as secondary air hence it provides cooling to the space without increase in moisture content. But in indirect evaporative cooling the cooling of primary air is limited to the wet bulb temperature of secondary air due to which it is not much effective. If the product air of the IEC system travels in a counter flow manner to the working air at an appropriate air-flow-ratio and across an infinite surface area, the temperature of the product air in the dry side of the plate will reach the wet-bulb temperature of the incoming working air. The temperature of the working air in the wet side of the plate will be lowered from its incoming dry- bulb temperature to the incoming wet-bulb temperature. How-ever, the actual effect is that only 40–80% of the incoming air wet- bulb temperature can be achieved [4]. The reasons for the reduced cooling effectiveness are investigated, giving identification of several attributing facts: (1) There is limited heat-exchanging-surface area; (2) none pure counter flow pattern could be achievable (3) Uniform and even water distribution over the wet sides of the plate is hard to obtain. The working principle and psychometric illustration of the air treatment process relating to an indirect evaporative cooling operation. During operation, the primary (product) air enter into the dry channel while the secondary (working) air enters into the adjacent wet channel. The primary air is cooled by the sensible heat transfer between the primary air and the plate, which is induced by the latent heat transfer relating to water evaporation from the plate's wet surface to secondary air. Hence the primary air gets cooled by constant moisture content, below figure2 shows the basic process of IDEC

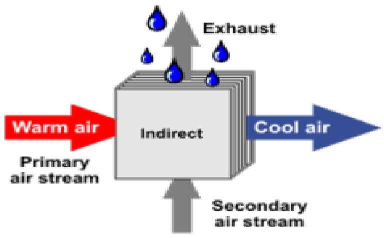

Fig.2 indirect evaporative cooling [5]

3. ENHANCED EVAPORATIVE COOLER:

3.1 M-Cycle IEC systems:

To enhance cooling performance of the IEC heat exchanger, a thermodynamic cycle, known as the M-cycle [6], was proposed by Professor Valeriy Maisotenko as the new approach of making and operating a heat exchanger. This cycle was claimed to enable harnessing extra amount of energy from the ambient using a dedicated flat plate, cross-flow and perforated heat exchanger. In the m-cycle heat exchanger the air flow through the dry channel and then some part of air escapes from dry channel and then entered to the wet channel known as secondary air which help to reduce the temperature of the dry channel without direct contact and then the secondary air escape out to the ambient atmosphere and then the primary air gets cool down and entered to the cooling space. The cross flow m-cycle heat exchanger cools the primary air below its wet bulb temperature that is why it is also known as dew point cooling, and it's cooling effectiveness is far better than conventional indirect evaporative cooling. Fig.3 shows the working of m-cycle heat exchanger.

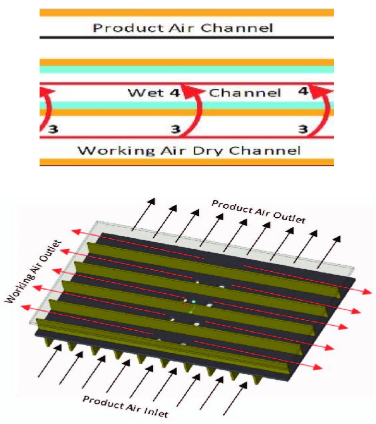

Fig.3 M-Cycle HX [7]

And by improving flow of water in the pad and by using various technologies in water spray we can improve the efficiency of IEC there are three water spray modes: external spray, internal spray and mixed internal and external sprays. The results show that the mixed mode performs best and internal spraying mode performs better than the external spraying mode does in terms of the wet-bulb efficiency, cooling capacity and the COP of IEC. The mixed mode improves the performance further by increasing wettability, the maximum wet bulb efficiency of (76%) achieved by the IEC operating in the mixed mode. The minimum wet bulb efficiency of 56.1% achieved by the IEC operating in the external mode. The internal spray mode improved the wet bulb efficiency in the range of 3.5–5.2% compared to the external spray mode. Most of the wet bulb efficiency values are within the acceptable range (above 60%) in the three water spray modes. The cooling load capacity increased by 12.5% with the internal spray mode and 25% with the mixed mode [8].

3.2 Liquid desiccant evaporative cooling system:

Liquid desiccant evaporative cooling is used to provide dehumidified which simultaneously gives human comfort. The common liquid desiccant that is being widely used is $CaCl_2$, LiBr, LiCl, try ethylene glycol (TEG) etc. the most favorable condition for liquid desiccant is it requires very low regeneration temperature in the range of 50-70^{0}C [9]. A desiccant based evaporative cooler using LiCl can provide 40-50% energy saving. Below figure 4 shows you the basic construction liquid desiccant evaporative cooling. However, there is some issue regarding their design some research is still under process these problems are Commonly associated the high equipment maintenance cost for the often-corrosive desiccant solutions, air leakage between the dry and wet streams and the need of large intake air stream to absorb the heat released during dehumidification

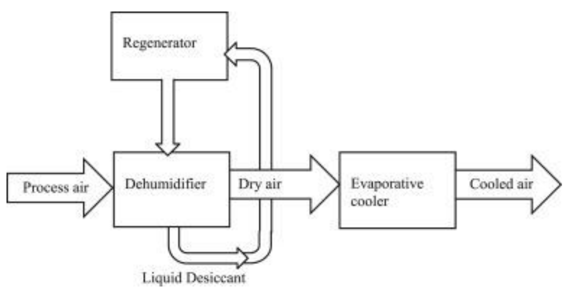

Fig.4 Liquid desiccant evaporative cooling [10]

3.3 Solid desiccant evaporative cooling system:

Fig.5 shows the effective desiccant wheel evaporative cooling. Desiccant wheel commonly known as rotatory dehumidifier. Desiccant wheel is used to dehumidify the ambient air and it is commonly fed up with solid desiccant, the wheel comprises of two part one is for the dehumidification and the other part is for the regeneration of solid desiccant so that it can be further utilised the desiccant wheel rotates so that it regenerates solid desiccant as well as dehumidify the ambient air, the regeneration of desiccant is carried out by some external agent which help to heat the return air so that it can achieve the regeneration temperature. Some common solid desiccants are silica gel, activated charcoal, calcium sulphate, calcium chloride etc. To increase the energy efficiency of desiccant wheel evaporative cooler the warm dry air stream coming from desiccant wheel first cool by return air then cool by evaporation. And the hot and humid air coming from the regeneration side of desiccant wheel is supplied to ambient atmosphere.

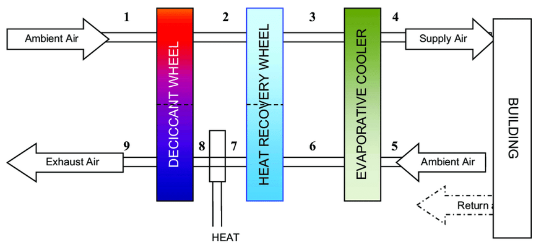

Fig.5 [11]

3.4 Membrane based evaporative cooling:

Desiccant based air cooling has the risk of contamination and deactivation and contamination of the desiccant by dust in the air stream. To overcome these problems membrane based cooling introduced in the evaporative cooling technologies. In membrane based evaporative cooling it can dehumidify the air as well as purify the air also, membrane is based on adsorption, they remove water vapours by adsorption and the remaining air tend to flow forward for effective cooling.

3.5 Liquid desiccant membrane assisted evaporative cooling:

In liquid desiccant based evaporative cooling we are facing many problems such as contamination, deactivation of desiccant due to the dust present in the air stream. To prevent these, we introduce membrane which helps to provide good quality air, increases drying efficiency, as well as increases the life of the liquid desiccant evaporative cooling. Fig.6 shows the arrangement of the system [12], as in this system the cold diluted liquid desiccant is first pass through the regenerator where it exchange it heat, after that it passes through the heat pump where the water gets evaporated and then it passes through the membrane where the vapours get dissolve with the ambient air which is then flow to the outside as hot and humid air. The liquid desiccant is now passes to the regenerator and then to the evaporative cooler so that it gets cool down and the cold liquid desiccant passes through the other membrane in a counter flow as of air which gets dry and cooled to provide cooling to the space, and then the liquid desiccant which gets humidified moves forward to the dehumidifier and the process repeats.

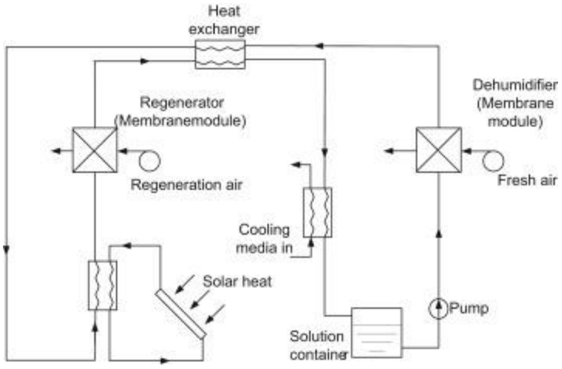

Fig.6 Membrane based liquid desiccant cooling [12]

4. Other application of evaporative cooler:

As we all know that our common desert cooler is used to cool the air but due to latent heat of vaporisation water get cooled simultaneously and we don't use it for the further purpose, also we know that during the summer the water stored in the overhead tank gets too hot and we are not able to use it or utilize it we don't even have any technology to cool the overhead water so by utilizing the cool water present in the cooler tank we can cool the water from the overheat tank. Also, Somwanshi and Tiwari proposed the utilization of the tank water of the desert cooler to cool the glass cover of a single slope, solar still, they found an increase in the output of solar still by 56% [13]. In the present work authors proposed the utilization of the coolness of tank water to cool hot water. As a basic model a cooper coil is placed inside the cooler tank and the water from overhead tank can flow inside the cooper tube which is then exchange heat with the cold water inside the cooler tank and then the water of overhead tank loose some heat and now it can be further used. Due to the heat exchange the water inside the cooler tank gets some heat which does not appreciably affect the performance of the cooler. It is seen that the cooler works very well in hot and dry climate due to high dry bulb temperature and low relative humidity. The average depression in the temperature of hot water is 12.6^{0}C, 12.9^{0}C and 8.6^{0}C for April, May and June. The total heat extracted from hot water is 1442.3 kWh and the cost of heat Extraction is Rupees 0.32/kWh. This cost is about 88% less than that of the conventional cooling system for extracting the same quantity of heat using electricity [14]. Fig.7 shows the basic working model construction. The performance of copper coil (heat exchanger) increases by increasing the length of coil and decreasing the mass flow rate of hot water flowing inside. With increase in length of copper coil from 10 m to 25 m, depression in temperature of hot water increases from 10.4_ C to 13.5 _C; with decrease in mass flow rate from 100L/h to 30 L/h depression in temperature of hot water increases from 10.5^{0}C to 14.0^{0}C.

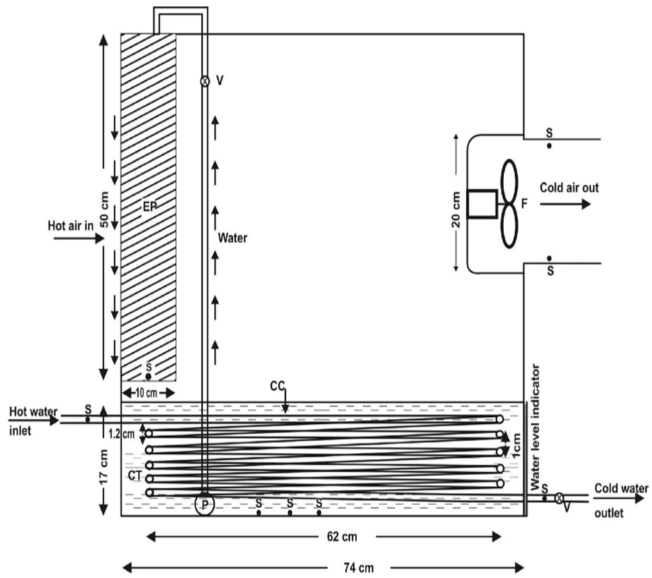

Fig.7 Hybrid air and water cooler [14]

5. CONCLUSIONS

Scientist are looking for the replacement of conventional vapor compression system to save environment as well as excess use of energy. So, till now the best is to replace it with an evaporative cooling and hence the scientist had made many changes to enhance the performance of evaporative cooling and the best is we can use pre- cooling of air with desiccant or with membrane and can be used as both for effective cooling and dehumidification of air.

And one more research is going on the evaporative cooler in which after the cooling of air the water which helps in cooling can be used as the drinking water and the end of the day. So the future of world is totally towards the replacement of modern VCRS system with evaporative cooling.

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