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Review Article

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Indirect Evaporative Cooling Systems – A Review

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Abstract The paper presents actual knowledge concerning the indirect evaporative cooling (IEC). This cooling technology is promising to develop in the near future due to its very low energy consumption and high efficiency in its range of applications. The review is presenting in details: theory, working principles, flow and construction. The IEC equipment and technology is suitable in different air conditioning applications: commercial, industrial, residential or data centres. The IEC technology is completely environmental friendly and has very low global warming impact. The single disadvantage of IEC is the water consumption. 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 The phenomenon of evaporative cooling is a common process in nature, whose applications for cooling air are being used since the ancient years. In fact, it meets this objective with low energy consumption, being compared to the primary energy consumption of other alternatives for cooling, as it is simply based in the phenomenon of reducing the air temperature by evaporating water on it. This process can be an interesting alternative to conventional systems in these applications where not very low temperatures are needed, like the case of air-conditioning during the summer. In this paper various types of direct and indirect cooling methods are reviewed to understand the various ways to attain cooling by these methods and provide alternative.

Keywords Indirect Evaporative Cooling, Seeback- PetlierEffect, Heat Exchangers.

1. Introduction

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

1.1 Direct Evaporative Cooling Systems

In direct systems, water evaporates directly in the air stream, producing an adiabatic process of heat exchange in which the air-dry bulb temperature decreases as its humidity increases. Thus, the amount of heat transferred from the air to the water is the same as the one employed in the evaporation of the water (Figure 1).

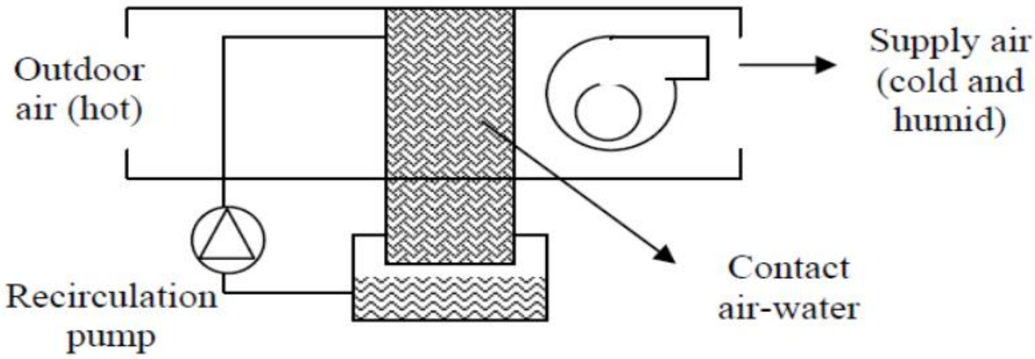

Figure 1: Direct Evaporative Cooling System

B. Indirect evaporative cooling systems

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 contamination, as no mass exchange is permitted between the two air streams (Figure 2).

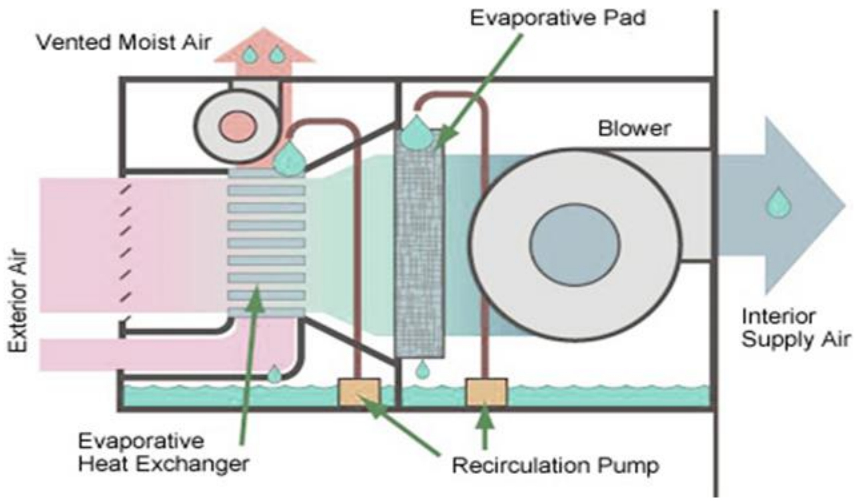

Figure 2: Indirect Evaporative Cooling System

2. Literature Survey

1.) Study of Performance and Possible Configuration of Hybrid Air Conditioning System with and without Combined Peltier Module and Earth Heat Exchanger

A study was carried out to investigate the performance and effect of Earth Heat Exchangers (Heat Pipe), Peltier Module with and without combination with vapour compression air conditioning system with return air. The results show that the coefficient of performance of the system can be improved and the energy required by the compressor can be reduced when Peltier Module and Earth Heat Exchanger is used before cooling coil and provide supplementary cooling air to evaporator coil. In the present age with depleting sources of energy there will be minimum electric power consumption in operation of the air conditioning units so that there is always a target to get the best energy ratios. Individually the ideas like Earth heat exchanger cooling; Peltier Module (thermoelectric cooling) did not stand good but by combination of two or more concepts in a collaborative manner stands a possibility to develop an energy efficient method of air conditioning.

By adopting proper design of Earth heat exchanger and modifying domestic refrigerator with Peltier Module can improve the COP as the best interesting alternative compared to other refrigerator system, for energy efficient applications based on the above concept experimental set-up is formulated. The Experimental set-up is tested with different combinations of VCC, Earth Heat Exchangers (Heat Pipe) and Peltier Module (thermoelectric module) for various performance parameters such as COP, compressor power reduction, temperature drop,, Refrigerating effect, Energy saving etc. The COP of the conventional 0.05 TR window type air conditioner is found to be increased from 1.8531to 2.8675 and energy saving is observed to be 12.75% with the combination of conventional 0.05 TR window type air conditioner with heat pipe heat exchanger and thermoelectric module.

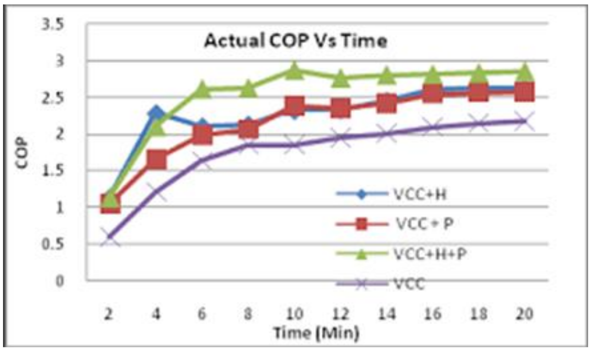

Figure 3: Design Development &Testing of Hybrid Air Conditioner Using Conventional Vapour Compression Cycle +Peltier Module +Earth Heat Exchanger

The experimental study of air conditioner working on VCC with combination of heat pipe (EHEX) and Peltier module lead to following conclusion: The maximum COP with all combination will rise to 2.85 as compared to the base case with 2.18. The Maximum percentage temperature reduction with all combination is 13.2% compared to the VCC with total energy saving slightly (negligibly) less than VCC + HP. The maximum energy saving is observed to be 33.3% with VCC + HP since heat pipe is a passive cooling enhancement. The refrigerating effect with all combinations will increase for the same time period.

2.) Increasing Energy Efficiency of Domestic Refrigerator using Single Thermoelectric Module & Water Cooling of Condenser

The study deals with hybrid refrigerator that combines thermoelectric (TER) and vapor compression refrigeration (VCR) and also entail experimental details of combined VCR & TER system. Objective is to configure hybrid refrigerator by introducing single Peltier module (TER) in domestic refrigerator and to analyze compressor cycles of conventional refrigerator with TER to increase energy efficiency of vapor compression cycle.

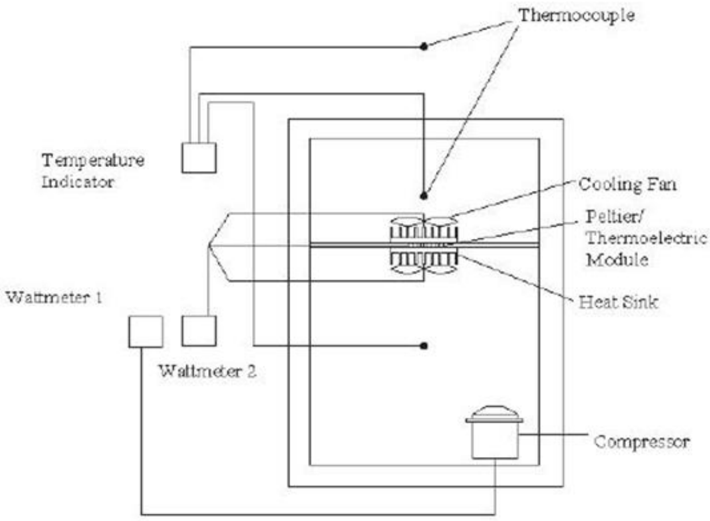

Figure 4: Schematic Diagram of Experimental setup

For this comparison of standalone VCR and Hybrid VCR+TER system is carried out. A Peltier module of size 4cm 4cm 0.4cm is introduced in the refrigerator cabinet & the effect on energy efficiency in terms of trip time of compressor is recorded. The effect of Air cooled & Water cooled condenser with TER in different structures is also investigated. It is observed that by introducing thermoelectric effect, energy efficiency of VCR is increased by almost 15.72 % annually. Thus ultimately improving COP of the hybrid system with better control on temperature over the total run time.

Present study deals with hybrid refrigerator that combines thermoelectric (TER) and vapor compression refrigeration (VCR) and also entail experimental details of combined VCR & TER system. Comparison of standalone VCR and Hybrid VCR+TER system with air cooled & Water cooled condenser is carried out. A Peltier module of size 4cm 4cm 0.4cm is introduced in the refrigerator cabinet & the effect on energy efficiency in terms of trip time of compressor is recorded. The effect of Air cooled & Water cooled condenser with TER in different structures is also investigated. It is observed that by introducing Peltier module during compressor trip time, run time of compressor is reduced. Out of two structures, structure 2 gives fairly good results. Using Peltier module in structure 2 intermediate supplyair cooled condenser, energy efficiency is increased up to 15.72% and almost 39 units of reduction per year compared to standalone VCR. As the refrigerator used for the experimentation is of old technology using R-12 as a refrigerant, reduction in consumed units can be increased up to 70-75 units per year in modern refrigerators. We can say that structure 2 with intermediate operation & air cooled condenser is best possible location of Peltier module in refrigerator. The study of this paper also concludes that, to achieve better COP & temperature control we can combine TER with VCR systems. Hence it is better to have such hybrid systems & devices to reduce total energy consumption.

3. Heat Exchange

Among this group of systems there are devices made of either tubular or plate heat-exchangers.

1. Indirect system with tubular heat-exchanger

The first reference to this kind of system comes from 1908, from a patent of a German inventor called Elfert. 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. Figure 5 shows the operation configuration of this kind of devices.

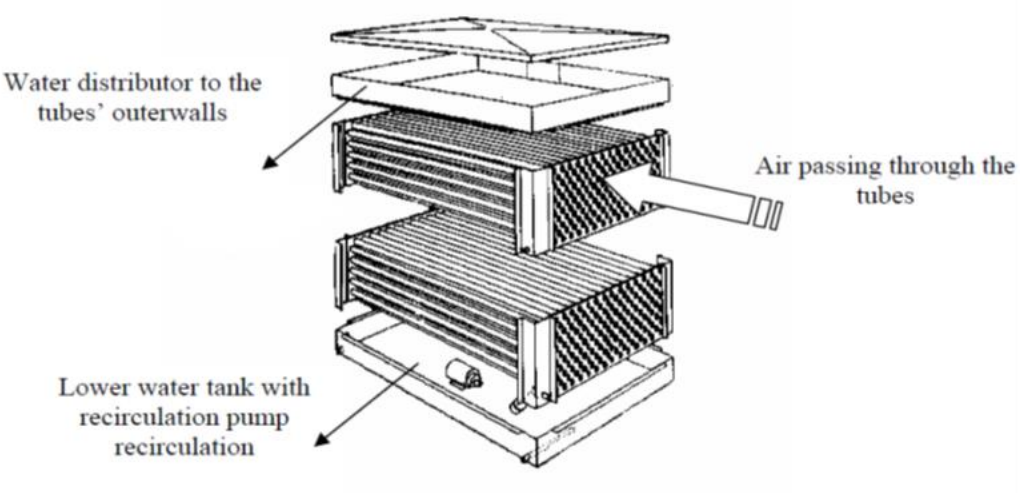

Figure 5: Tubular indirect evaporative cooler

2. Indirect 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.

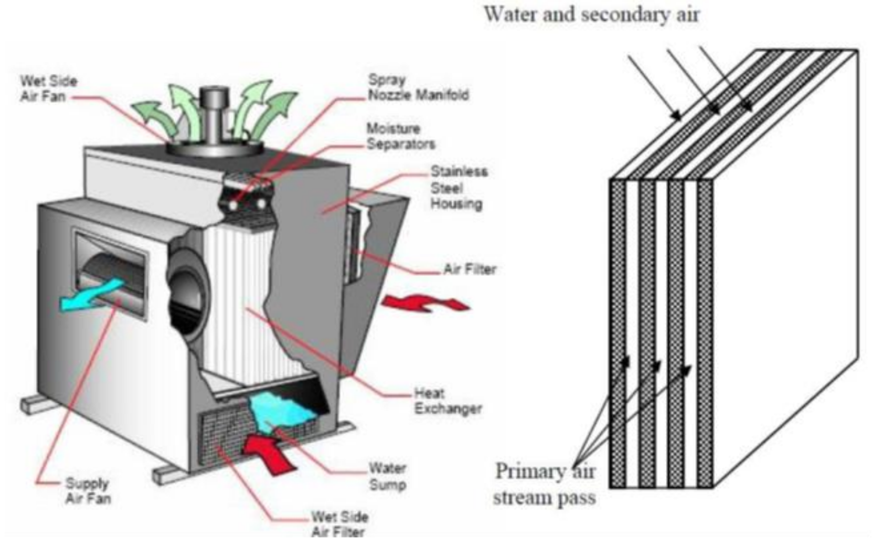

Figure 6: Configuration of the plate indirect evaporative cooler

C. Mixed evaporative cooling systems

The mixed systems aim to combine the two cases described (direct and indirect) through a sequence of stages, in order to improve the efficiency and stretch the possibilities of the application of this phenomenon in humid climates (Figure 7).

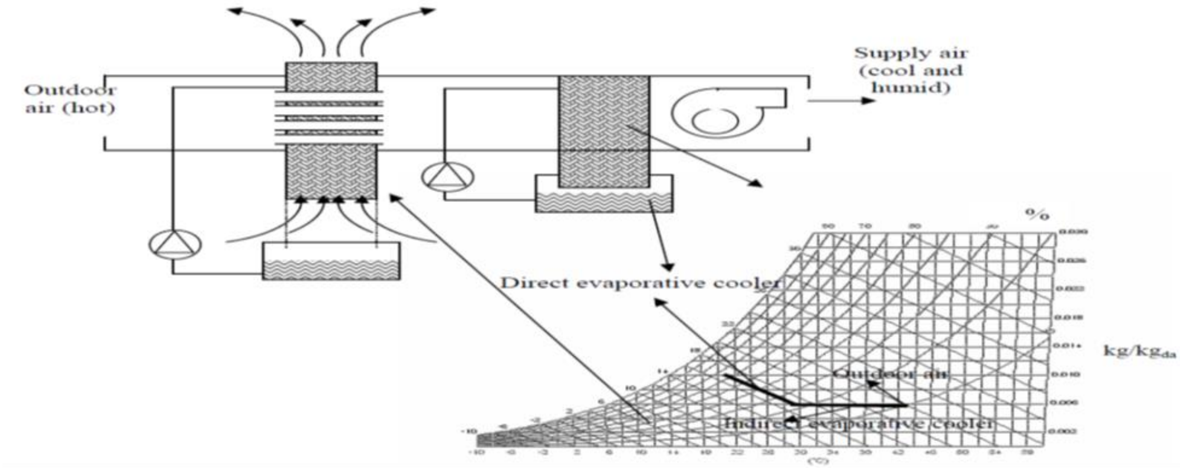

Figure 7: Configuration and psychrometric evolution for a mixed evaporative cooler

4. Conclusions

Different types of Indirect Evaporative Cooling Techniques have been reviewed by the author. As Indirect Evaporative Cooling is a rapidly advancing technique, the author proposes a vide range of advancements or inclusions to adapt the technology to suit the future trends and markets. The author proposes Hybridisation of Thermoelectric & Indirect Evaporative Cooling system for energy efficient low power cooling, Use of indirect evaporative cooling with high surface area contact caging to provide evaporative cooling without adding humidity to air, Adaptive humidity , if air is dry/rough , Integration of wind Quility Filter &anearobicfreshner& air perform enhance the leisure, Use of forced petlier cooling, to produce rapid cooling when Indirect Evaporative cooling is taking time, & automatic change over to Indirect Evaporative cooling when desired cooling rate is settled for low power consumption. Also the design allows for use of natural air recirculation thus maintains freshness of the cooled area. The direct advent at Non CF, Air Conditioner, the reducing the carbon Root print Orastically according to Global Comption Needs

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