

Comparison of Air Cooled and Evaporatively Cooled Refrigeration Systems – A Review Paper

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Abstract

The air cooled condensers are widely used as they are less costly and give satisfactory performance. But their performance is greatly affected by the temperature of cooling media which is ambient air. To deal this problem we can use water cooled condenser. But their cost and maintenance limit their use. The performance improvement of Air cooled condensers can be achieved by using evaporative cooling. This method may prove quiet effective and less costly. There are researchers working on the above issue. Few of them have successfully implemented the research in practice. The paper deals with a few papers using the evaporative cooling. The applications include domestic as well as industrial.

Key words: Air cooled condenser, Evaporative cooling

I. INTRODUCTION

The vapor compression system is widely used in various cooling applications. The basic components and various processes are as shown in figure.

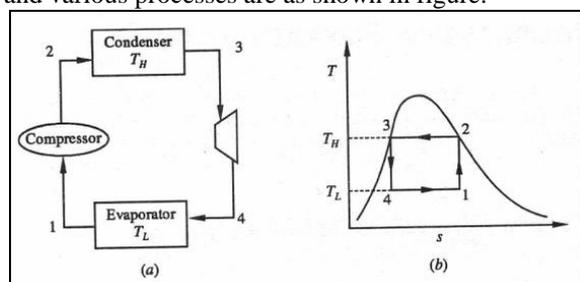


Fig. 1.1 Vapour Compression Refrigeration Cycle

Process 1-2 : Isentropic compression from wet vapour to saturated vapour.

Process 2-3 : Isothermal Heat rejection in the condenser.

Process 3-4 : Isentropic expansion from wet liquid.

Process 4-1 : Isothermal Heat absorption in the evaporator.

The COP of the cycle depends upon various parameters like sub cooling, superheating, suction & discharge pressure of the compressor. COP is also greatly affected due to power consumption of the compressor as it is a major power consuming element. Depending upon the cooling load, the power consumption of the compressor will change. Suction & discharge pressure also greatly affect compressor energy consumption.. Increase in the condenser temperature increases condenser pressure and hence compressor work . It also decreases cooling capacity of the cycle due to the reduction of liquid content in the evaporator. These two effects decrease performance of system considerably.

In a vapor compression system where an air cooled condenser is used , Temperature of air cooled

condenser depends upon the ambient temperature. Higher condenser temperatures are not desirable as it decreases COP of system. In hotter environment it may sometimes even trip the compressor.

This review paper discusses a few papers dealing with this problem.

II. LITERATURE SURVEY

Eghtedari H. et al. [1] investigated about the Application of evaporatively cooled air condenser instead of air cooled condenser to solve the problem of maintaining higher COP in hot weather conditions. He built An evaporative cooler and coupled it to the existing air-cooled condenser of a split air conditioner in order to measure its effect on the cycle performance. . Experimental results showed that application of evaporatively cooled air condenser has significant effect on the performance improvement of the cycle and the rate of improvement increases as ambient air temperature increases.

Hajidavalloo Ebrahim [2] investigated incorporation of evaporative cooling in the condenser of window-air-conditioner. An air conditioner was used to test the innovation by putting two cooling pads in both sides of the air conditioner and injecting water on them in order to cool down the air before passing it over the condenser.

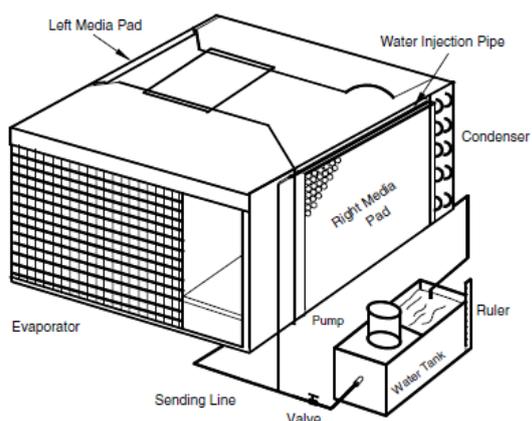


Fig.2.1 . Experimental Setup

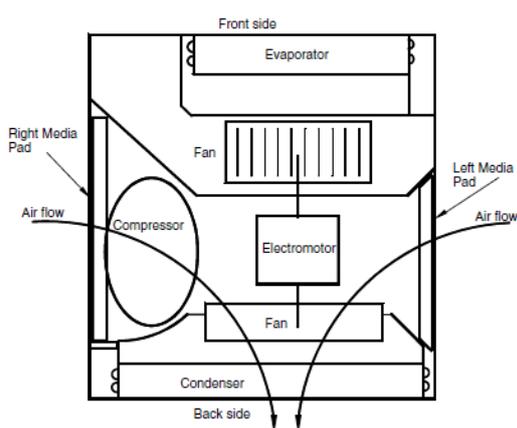


Fig.2.2 . Schematic View of Experimental Setup

The experimental results show that thermodynamic characteristics of new system are considerably improved. The power consumption decreased by about 16% and the coefficient of performance increased by about 55%.

Chan et al. [3] described how direct evaporative coolers can be used to improve the energy efficiency of air-cooled chillers in various operating conditions and with different strategies for staging condenser fans. These coolers are installed in front of air-cooled condensers to precool outdoor air before entering the condensers. With the direct evaporative cooler, compressor power dropped following the decrease in the condensing temperature in most operating conditions, while the pressure drop across the cooler caused additional condenser fan power. The overall saving of chiller power varied from 1.4 to 14.4%

Hassan et al. [4] studied an innovative condenser for residential refrigerator. To allow for evaporative cooling, sheets of cloth were wrapped around condenser to suck the water from a water basin by capillary effect. The arrangement is as shown in figure.

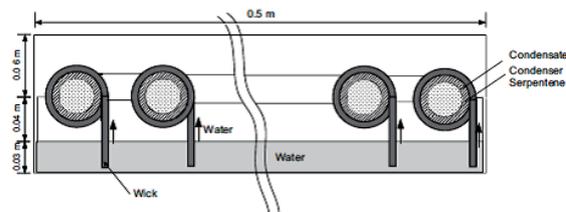


Fig.2.3 . Condenser tubes with evaporative cooling

The experimental results were crosschecked by building a theoretical model of the system Yang et al.[5] investigated about application of mist evaporative precooling to air cooled chillers.



Fig.2.4 . Water mist precooling

The experimental results showed that the dry bulb temperature of entering condenser air with water mist pre-cooling could drop by up to 9.40 C from the ambient air temperature. COP could be improved by up to 18.6%. This study showed that the water mist system coupled to air-cooled chillers is an energy efficient and environment friendly technique.

Kopko et al. [6] investigated evaporative cooling and conventional cooling for a split heat pump system. The evaporative condenser was retrofitted onto an existing split heat pump system. For the purpose of this test heat pump only operated in cooling mode. Two separate sections maintained indoor & outdoor conditions for the respective units.

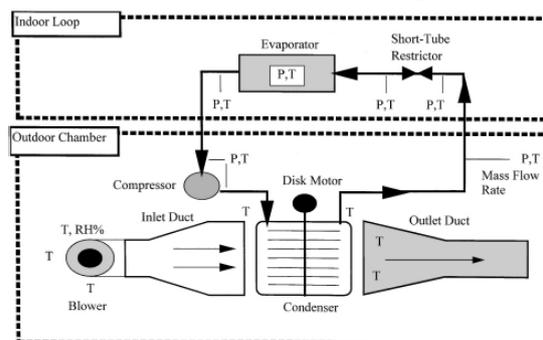


Fig.2.5 . Block diagram of the system

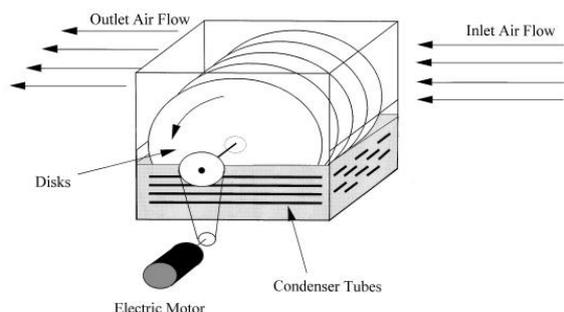


Fig.2.6 . Evaporative Condenser

In the evaporative condenser, as the disks rotate, their wetted surfaces pull a film of water out of the bath into the air stream. The passing air evaporates some of the water film, cooling the water that remains on the disks. This cooled water is returned to the bath as the disks rotate, cooling the bath and thus the condenser tubes.

The final results showed improved steady state performance; a higher capacity of COP by 11.1 to 21.6%.

R. Boukhanouf et al. [7] presented a computer model and experimental results of a sub-wet bulb temperature evaporative cooling system for space cooling in buildings in hot and dry climates. The cooler uses porous ceramic materials as the wet media for water evaporation.

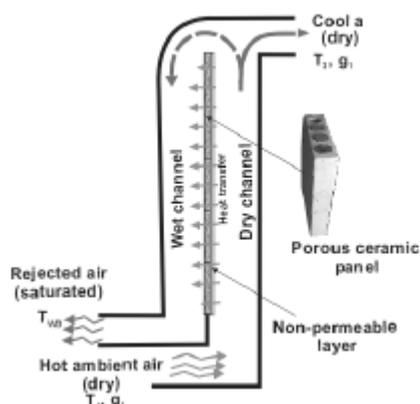


Fig.2.7 . Schematic diagram of porous Ceramic Evaporative cooler

The porous ceramic panels were placed between the dry and wet air ducts to form small and narrow ducts with air flowing at low velocity. The dry channel side of the porous ceramic panel is sealed with a thin non-permeable membrane while the wet channel side allows water to sip through its micropores onto its surface forming a thin water film. This allows direct contact with the airflow and hence causing water evaporation. The air streams in the dry and wet channel flow in counter flow arrangement and the supply air exchanges sensible heat with the water in the porous ceramic panels that in turn are cooled through water evaporation on the wet channel side. This results in a drop in temperature of the air in

the dry channel without changing its moisture content while the air in the wet channel is rejected at saturation state.

Under selected test conditions of air flow dry bulb temperature of up to 45o C and relative humidity of up to 50%, it was found that the supply air could be cooled to below the wet bulb temperature with a maximum cooling capacity of 280 W/m² of the wet ceramic surface area. It was also shown that the overall wet bulb effectiveness is greater than unity. This performance would make the system a potential alternative to conventional mechanical air conditioning systems in hot and dry regions.

K.A. Jahangeer et al. [8] concentrated on lowering of the condensing temperature will help to reduce compressor pressure lift, thereby reducing the power required by the compressor. This paper reports a numerical investigation of the heat transfer characteristics of an evaporatively-cooled condenser. A detailed model is developed and numerical simulations are carried out using finite difference techniques. The simulations are performed for a single unfinned tube of the condenser with the air flowing across the tube. Water is sprayed on top of the tube in the form of fine sprays and the flow rate is set to achieve film thicknesses of 0.075, 0.1, and 0.15 mm, respectively. The tube wall temperature is assumed constant due to the fact that for most of the tube length, condensation of the refrigerant occurs at the saturation temperature of the refrigerant. Wall to air overall heat transfer coefficient value as high as 2000 W/m² K was observed with the incorporation of the evaporative cooling.

III. SUMMARY

The air cooled condensers have low capital and running cost as compared to water cooled condensers. But the dependency of air cooled condensers on the ambient air temperature prevents it from giving a constant performance. Here the water cooled condensers prove beneficial as their performance is independent of the atmospheric temperature. A golden mean has to be achieved. There are lot of investigations carried out on the performance improvement of air cooled condensers using evaporative cooling. The evaporative cooling is generally achieved by evaporating some portion of water which will cool the remaining water. The evaporating cooling may be direct or indirect. Depending upon the atmospheric conditions and system parameters either may be more effective. From the papers reviewed here it can be concluded that the performance of air cooled condensers can be improved up to some extent. Many different methods like using cooling media, water mist spraying etc. can be used. There is scope for exploring different cooling media's. Many other different innovative methods for evaporative cooling can still be developed.

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