Experimental Investigation of Evaporative Condenser with Two Cooling Pads for Window Air-Conditioner

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Abstract

The increased power consumption and with limited recourses, it is important to save energy and reduce carbon foot prints. The tropical climate like of India, summer conditions have higher temperatures by 5^o to 10^o C in daytime temperature over last two decades. So the demand of air-conditioners increases by 30% per year. Nowadays air-conditioning is not a luxury, with time it becomes necessity. Considering these issues, enhancement of Coefficient of Performance (COP) of air conditioners and reduction in their power input is the matter of interest. In this paper evaporative condenser with two cooling pads is developed. It is observed from the results that with this type of condenser power consumption decreases by about 15% and the coefficient of performance increases by about 50%.

Key Words: Condenser, Cooling Pads, COP, Power Consumption.

1. INDRODUCTION

Due to energy crisis and global warming much attention is diverted on strategies for saving energy. Due to simplicity and flexibility, window air conditioner is generally used in residential and commercial buildings. The condenser used in this system for heat rejection process is generally air cooled, it seems reasonable as far as the air temperature in summer is moderate and not too high (about 40^o C). But when the air temperature increase and approaches 45^o C or higher the performance of air condenser drops down and the air conditioner work improperly. Since the temperature and the pressure of the condenser increases and the compressor is forced to work under the greater pressure ratio which result in more power consumption. Another problem which was reported with application of air condenser in hot weather area is related to the high stories buildings. In these buildings the hot air from air conditioners of lower stories rises up and provides a hot flow field around the air conditioners of higher stories. The coefficient of performance (COP) of an air conditioner decreases about 2–4% by increasing each ^{o} C in condenser temperature [1-2].

The effect of evaporative cooling to increase COP and reduce power consumption in large industrial refrigeration systems were investigated [3-4], but there is negligible work to investigate the application of evaporative cooling on small size refrigeration system. Goswamiet. al. [5]employed an evaporative cooling on existing 2.5 ton air conditioning system by using media pad. They put four media pad around condenser and inject water from the top by a small water pump. They reported the electric energy saving of 20% for the retrofitted system.E. Hajidavalloo[6]investigated the effect of media cooling pads on COP of air-conditioners.

Mechanical sub-cooling in vapour compression system can also be employed but these methods are costly and needs costly equipments [7-8]. Some other researchers also investigate other methods [9-11].

Water cooled condenser with two cooling pads on the sides from where condenser sucks air for cooling is designed and used in this work. It is observed that with the new developed condenser power consumption decreases by about 15% and the coefficient of performance increases by about 50%.

2. EXPERIMENTAL SETUP AND PROCEDURES

Different designs for applying evaporative cooling in an existing residential air conditioner could be introduced. Concern should be taken to employ a design with best performance and minimum side effects. The heat is rejected in the condenser unit of window air conditioner, so to modify it we can use two methods for evaporative cooling in condensers namely direct and indirect method. In direct method water is directly injected on the condenser and provides cooling effect. In the indirect method water is injected on the evaporative media pad which is located in the way of air over the condenser and provides cooling effect by evaporation of water. In this study both methods of evaporative cooling is combined and used to take maximum benefit out of these methods. Two side pads used are of cellulose bound cardboard structures which are cross-fluted to increase the contact area between air and water. The average life expecting of the media pad evaporative cooler is of the order of five years. With clean water it may last up to 10 years [12-13]. The location of pads is an important aspect of the design as they solely affect the performance of air-conditioner. The cooling pads should be placed where it gives the best cooling performance and also takes minimum space.

In this work two evaporative cooling pads along with direct atomization of water on condenser are used. Each with 2.5 cm thickness were installed in both sides to give the largest area for cooling without increasing the total volume of the air conditioner as shown in Figure 1. Hot ambient air passes over the evaporative media pads and after cooling down passes over the condenser and finally exits from back side of the condenser. Hot air passes over these cooled pads and passes through the condenser, after providing cooling effect; it exits from the back side of condenser as shown in the Figure 2.

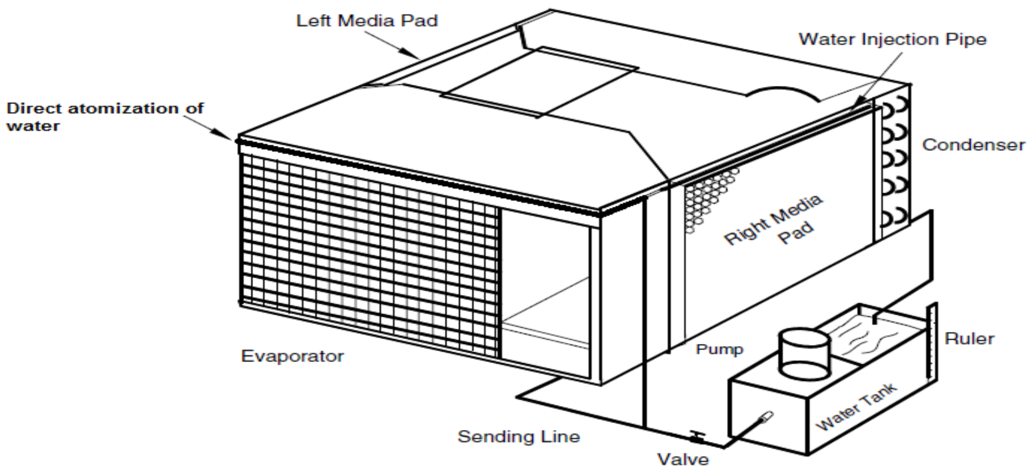

Fig-1.Schematic diagram of the modifiedair-conditioner

A water circulation system was incorporated to spray water on the top of the cooling pad. It includes a small pump, tank and water spraying pipe. Energy meter was used to measure the electrical current consumption of the compressor, condenser and evaporator fan and water circulation pump.

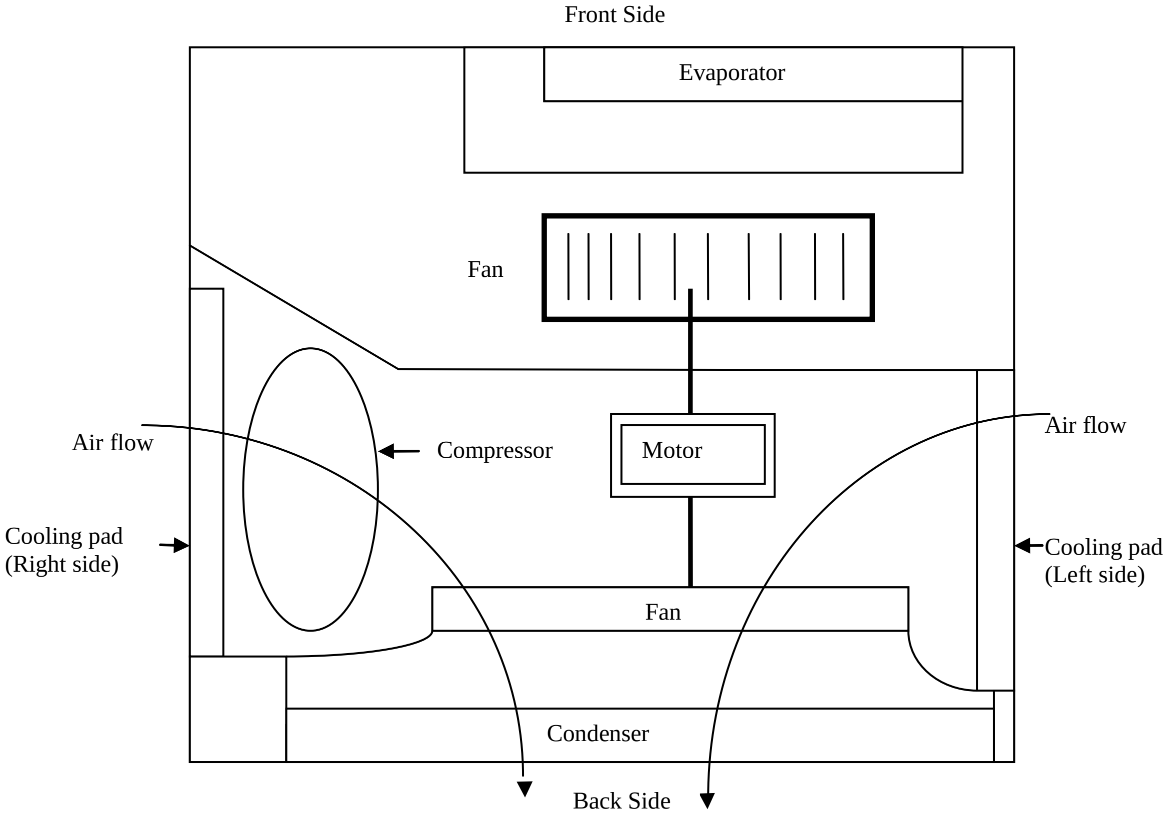

Fig- 2 Plan view of the modifiedair-conditioner

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

Experiments were performed as per design of experiment analysis to prepare the set up for acquiring reliable data. In order to have a basis for comparison and also to specify the effect of evaporative cooling on the air conditioner, each experiment was performed in two consequent parts. Experiments are performed in two parts in the first part, conventional air conditioner was used in the experiment without using cooling pad and the data were recorded after steady state condition was established. Then, in second part the evaporative condenser with two cooling pads are used in air conditioner. The time difference between two stages was small (about one hour), so the weather condition for two experiments was the same.In all experiments the data were recorded after steady state condition was established and the properties of refrigerant and air remained constant. The results of experimental measurements of different parameters for conventional and modified air-conditioner are presented in Table1 and Table 2.

Table1. Experimental measurements for modified (with evaporative condenser)

Time (min.)	Energy (kWh)	Pressure(Mpa)		Temperature (^oC)				
		P_1	P_2	T_1	T_2	T_3	T_4	T_5
00	25.4	22.5	4.2	44.6	22.2	43.5	19.5	85.6
20	26.1	22.1	4.1	43.8	21.6	29.5	19.2	83.2
40	26.7	23.9	3.9	43.9	21.1	28.5	19.1	82.5
60	27.4	23.7	4.1	44.1	20.8	27.9	18.4	80.3

Table 2.Experimental measurements for modified (with evaporative condenser)

Time (min.)	Energy (kWh)	Pressure (Mpa)		Temperature (°C)				
		P_1	P_2	T_1	T_2	T_3	T_4	T_5
00	23.0	24	4.5	49	23.2	43.2	24.2	85.6
20	23.8	25.1	4.6	53.5	25.4	43.5	23.7	88.5
40	24.7	26	4.8	54	26.4	44.2	22.8	90.2
60	25.4	26.6	4.85	55	27.6	44.8	21.6	94.3

Where T_1-Compressor outlet,T_2- Evaporator Outlet,T_3-Side cooling pad Temperature, T_4-Evaporator inlet,T_5- compressor outlet, P_1-Suction pressure at compressor, P_2-Discharge pressure. The p-h chart drawn from the values taken from Table 1and Table 2is shown in Figure 3. It is observed from the p-h chart that with evaporative cooling the work done required is reduced and refrigeration effect also increases i.e. power consumption reduces and COP increases.

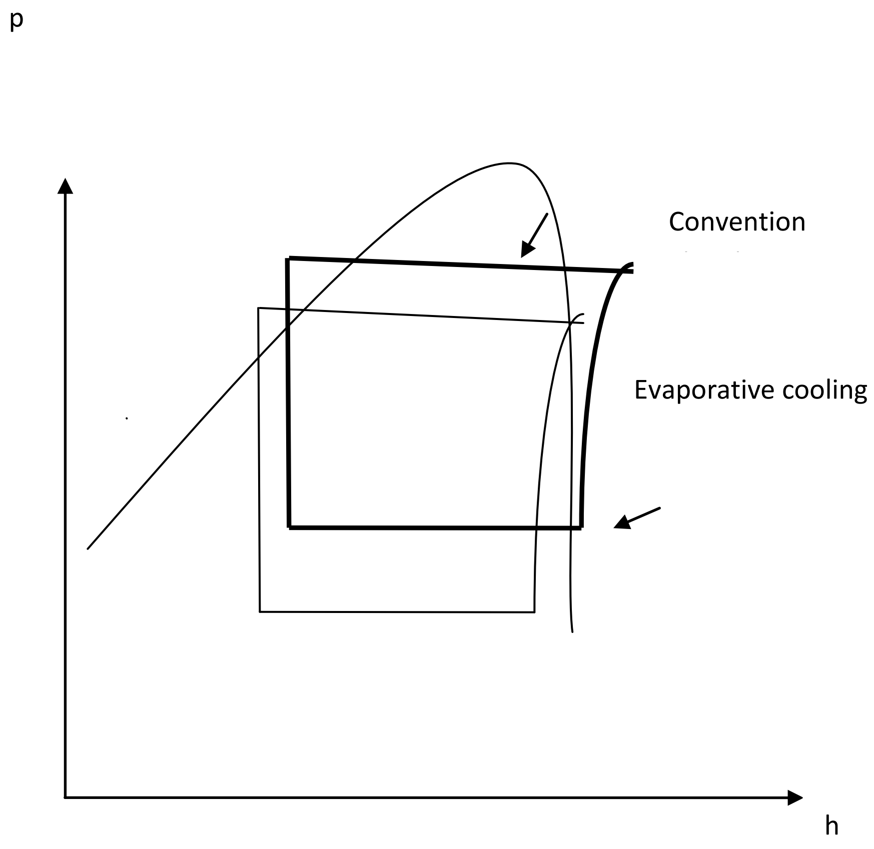

Fig- 3 The p-h diagram for conventional and modified cooling cycle.

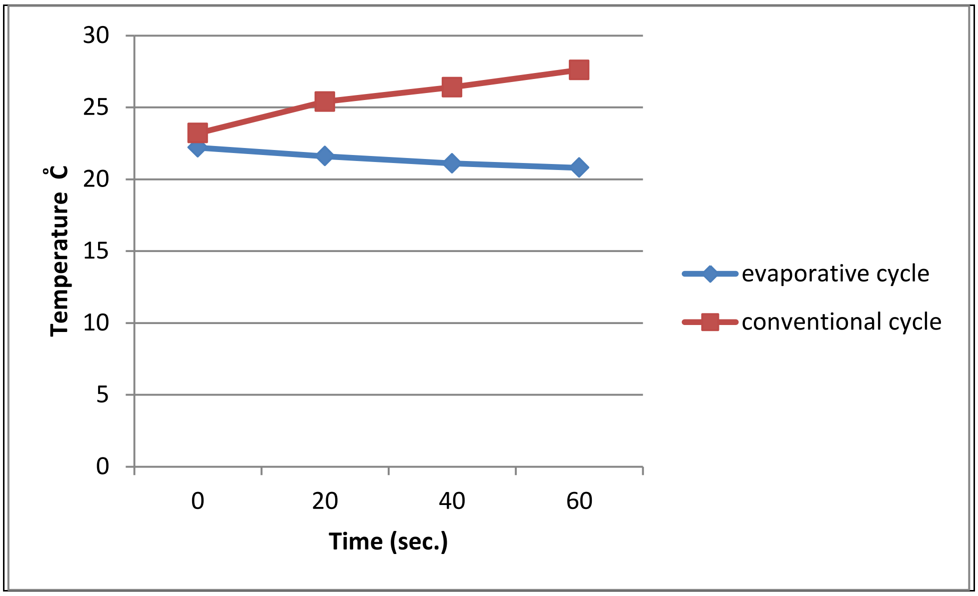

Fig- 4 Evaporator outlet temperature

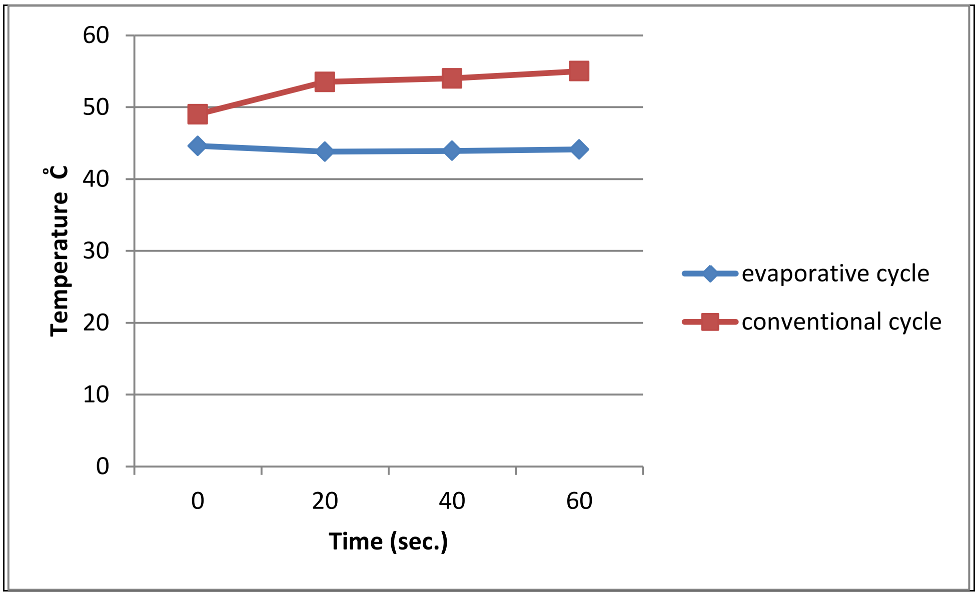

Fig- 5 Condenser outlet temperature

The Figures 4-5 shows the comparison of evaporator and condenser outlet temperatures. It can be seen from the figures with the employment of evaporative condenser and two cooling pads, the temperatures of both evaporator and condenser outlet decreases and helps to decrease power consumption and in turn increasers COP. The overall results show that power consumption decreases about 15% and cooling capacity increase about 31%. Refrigerant effect increase 19%. The COP which is the most important parameter increase about 50%. This indicates that by employing evaporative cooler not only power consumption decreases but also cooling capacity also increases.

4. CONCLUSIONS

A design for employing indirect and direct evaporative cooling system in a window-air-conditioner was introduced. It is found that the evaporative cooling can be effective and economical for the regions of very hot weather. This system can be retrofitted easily on existing equipments, so commercialization of this design is very high and it could also be easily applied on existing air conditioners. It was recommended to use evaporative condenser in summers instead of conventional air condenser to save electric power and increase cooling capacity. Economic analysis based on local prices shows the energy saving can pay for the cost associate with retrofitting the condenser in less than 1 year.

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