Experimental Evaluation and Performance of Window Air Conditioner by Using Pre-Cooled Air in Condenser

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Abstract- Reduction of energy consumption is a major concern in the vapor compression refrigeration cycle especially in the area with very hot weather conditions (about 50 ºC), where window-air conditioners are usually used to cool homes. Research programs in order to improve the performance of window-air-conditioners by enhancing heat transfer rate in the condenser. In this system air is cooled outside the window air conditioner, and this cold air is fed over the condenser tubes. After to this greater amount of heat rejected from refrigerant vapor and low condensation pressure is obtained, which in turn increase Coefficient of performance (COP) of air conditioner. Air is pre-cooled in a device, in which atmospheric air is directly contact with water which comes from top of the device in fine droplets. Due to contact between air-water, air is cooled and passes to air conditioner. Practical performance shows that, by this arrangement reduces power consumption and improving performance of air-conditioner.

Keywords- *Window air conditioner, Pre-cooler with air washer, COP, Water injection, Energy reduction.*

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1. INTRODUCTION

The energy conservation is in demand. The aim is the Air conditioner works with lower power consumption. For summer season, outside atmospheric temperature of air is increase up to 40ºC to 50ºC. Where window air conditioner is use to cool room. But condenser performance decreases due to higher atmospheric temperature and consumption of power is increases.
The COP of an air conditioner decreases about 2–4%, The COP of an air conditioner decreases by 40% in hot weather condition. Due to large reduction of COP means more electric power consumption for window air conditioner.

Due to higher temperature window air conditioner is tripe due to load on compressor. The increase in the air temperature is so high because of that the air conditioner trip down. In order to prevent this problem, the hot air is required to be cool down before passing over the condenser. New design with evaporative cooling system improves performance of window air conditioner and better heat transfer rate in condenser of window air conditioner.

1.1 Window Air Conditioner With Air Pre-Cooler

Instead of using atmospheric air to cool condenser coil, cooled air used for following reasons:

- Temperature decreases during air travels inside pre-cooler.
- Cooling of air is done outside the window air conditioner in pre-cooler.
- Air sucks from pre-cooler to air conditioner box due to pressure difference of air outside and inside the air pre-cooler
- Very low velocity of air travel does not contain water particle with it.

Goswami 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 when ambient air temperature was 34 ºC.[1] Hajidavalloo investigated the effect of evaporative cooling of window-air-conditioner by injecting water directly on the condenser and reported 10% reduction in power consumption.[2] Bogdan et al. reviewed indirect evaporative cooling (IEC) operating conditions and performances. 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 of operating conditions and performances, having very low energy consumption comparing to classic cooling. The IEC technology is environmental friendly and has very low global warming impact. The single disadvantage of IEC is the water consumption.[3] Mansi Jayswala examined the energy conservation potential of passive & hybrid down-draught evaporative cooling for commercial buildings. The findings clearly suggest that while energy efficiency can be significantly achieved through building regulations/ECBC codes and appropriate choice of materials/ construction technology, but the potential for energy efficiency is much higher when such measures are integrated into the design philosophy and approach.[4] Bogdan Porumba and Raluca Porumba worked on indirect evaporative cooling to reduce the energy consumption in fresh air-conditioning applications. The classic system was considered composed of a cooling battery powered by an electric chiller and the evaporative system was considered composed by a recuperative heat exchanger, indirect evaporative cooling equipment and the same classic cooling battery. It was found that the fresh air cooling period starts in May and ends in September. The performances of the two air conditioning technologies were compared and it was concluded that the evaporative system allowed the reduction of energy consumption for the fresh air cooling with almost 80%.[5]

1.2 Nomenclature

Cooling effect – kw
Power consumption – kw . hr
Pressure – Kpa
Enthalpy - KJ/Kg
Temperature - ℃
Inlet air enthalpy = h_2
Outlet air enthalpy = h_1

2. SYSTEM DESIGN AND EXPERIMENTAL SET-UP

Simple window air conditioner is used with modified design of pre-cooler. In this system pre-cooler is fixed at side of outside hot side box of air conditioner, so instead of atmospheric air for cooling of condenser of window air-conditioner pre-cooled air from pre-cooler is supplied to condenser.

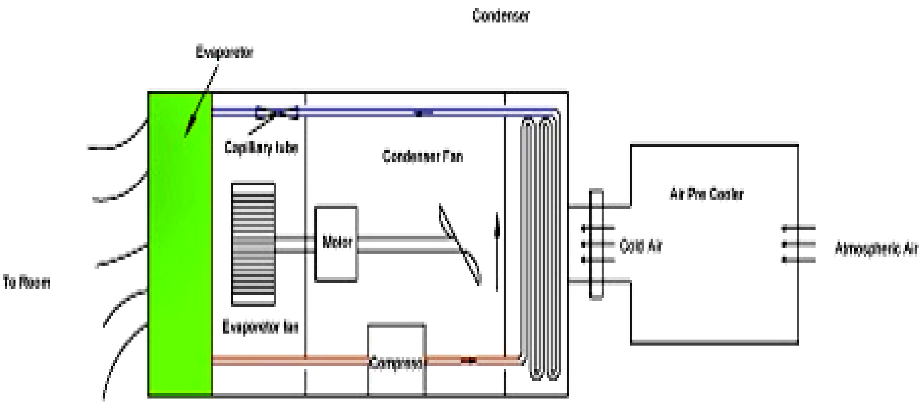

Figure 1. Modified Design of Window Air Conditioner

Air pre-cooler is made from acrylic sheet and holes are made on top surface of cooler. Water drops down through holes and come in contact with air passing in pre-cooler, due to this air temperature drops down, this cold air circulate around condenser coil which gives better condenser performance. System runs with pre-cooler and without pre-cooler and readings are taken in both cases and comparing the reading.

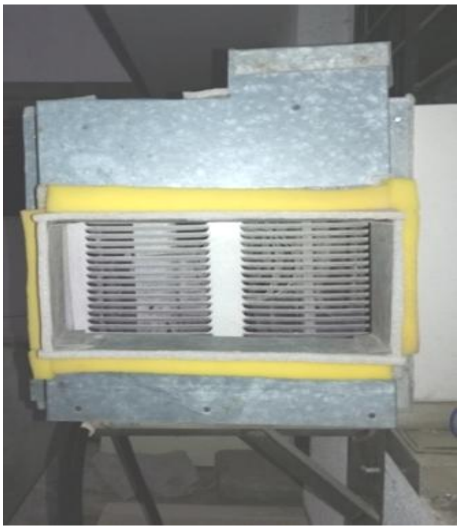

Figure 2. Pre Cooler Area of Window Air-Conditioner with Duct and Passage for Air Pre-Cooler

Figure 3. Shows Passage at which Pre-Cooler is fixed with Window Air-Conditioner

2.1 Main Parts of Window Air Conditioner by Using Pre-Cooled Air in Condenser.

1. Compressor
2. Condenser
3. Evaporator
4. Expansion Device
5. Air Pre- Cooled Device

2.2 Main Parts of Pre-Cooler

- Cabinet made of acrylic sheet of dimension (300×300×380)
- Duct from Galvanized iron Sheet.
- 12v D.C. supply pump.
- Inlet and outlet pipe.
- Top surface of pre-cooler (1 mm diameter hole with Equal space of 2.5 mm between two holes)
- Air washer.

2.3 Instruments used

- Temperature and humidity meter
- Energy meter
- Clamp multi meter
- Sling phychrometer
- Anemometer
- Digital temperature meter.

2.4 Procedure

1. Window air conditioner of 1 ton capacity is purchased from market which has compressor motor is of 1hp and working refrigerant is R22 is used.
2. Slot is made on window of room.
3. Duct is made from G.I. sheet for suction of air inside hot side of window air conditioner through air pre-cooler.
4. After fixing of duct on sides of outside box of window air conditioner the pre-cooler is attached at one side of hot region box.
5. Pump use to lift water in pre-cooler is connected to energy meter for power supply, and window air conditioner also connected to same energy meter so, total power use for operation can be read from same energy meter. Here total power is sum of power use to run pump and to run compressor of window air conditioner.
6. While operation done with pre-cooler switch ON the switch for pump power supply so total power can be read from energy meter.
7. While operation done without air-pre cooler switch OFF the pump power supply switch.
8. Run window air conditioner for one hour to obtain steady condition.
9. Take outlet air temperature and inlet air temperature (DBT, WBT)
10. Measure area of air outlet through cold air enters inside room take reading of velocities by digital anemometer. Take number of readings at different section of air outlets. And find average velocity of air.

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11. Pressure gauges are fixed to measure inlet and outlet pressure of refrigerant passes to compressor.
12. Four temperature sensors are fixed to note down temperature of refrigerant at different points on condenser coil.
13. Two temperature sensors are used to measure evaporator inlet and outlet refrigerant temperature.
14. From pressure enthalpy diagram find out work consumption of compressor and cooling effect produced in refrigeration system.

2.5 Air Tight Duct

In simple window air conditioner grills are provided on top and sides of window air conditioner though which atmospheric air is enters inside hot side of window air-conditioner.

Duct made from G.I sheet is fitted on sides of window air conditioner which covers the grills through which air enters for cooling condenser coil, only slot is open at which air pre-cooler is fixed.

By providing duct, vacuum is created inside the hot side system of air conditioner and atmospheric air is drawn naturally through opening of air pre-cooler.

Due to rotation of condenser fan, pressure difference causes air draws inside the window air conditioner hot side region.

Pump is used to lift water in pre-cooler and water is fall down through holes.

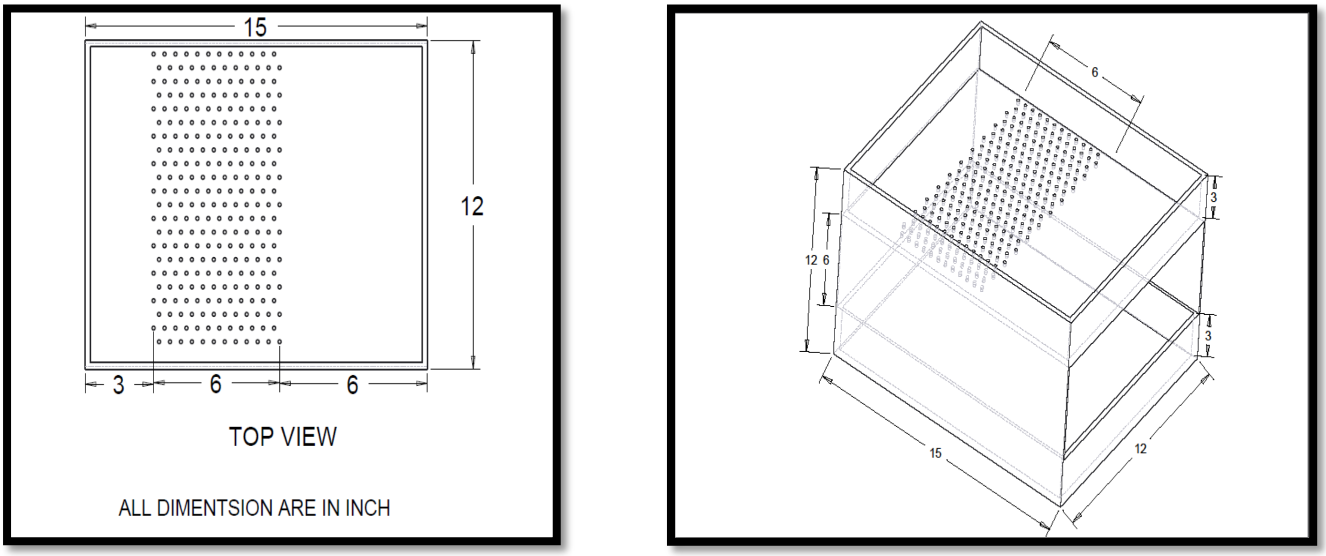

Figure 4. Design of Pre-Cooled Air in Condenser

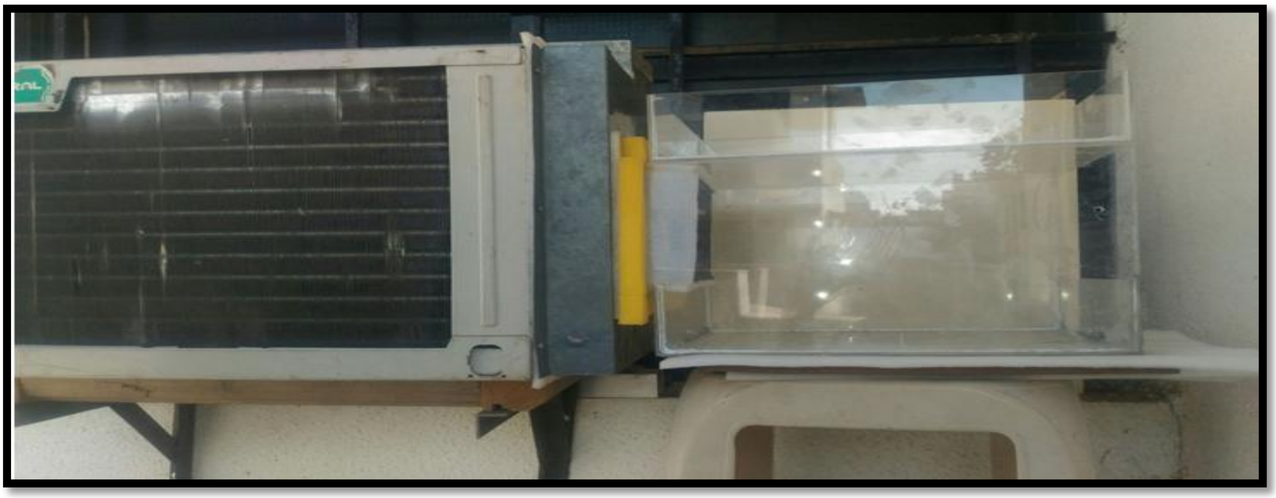

Figure 5. Actual Set of Pre-Cooled Air in Condenser

2.6 Formulas used for Calculation

$V_{av} = (V_1 + V_2 + V_3 + V_4 + V_5 + V_6 + V_7 + V_8 + V_9)/9$

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Quantity of air delivered in m^3\sec

Q = Area× velocity

Mass flow rate of air in kg\sec;

W = Q × density of air

From psychometric chart;

Cooling effect produced $= w\ (h_2 - h_1)$

Power consumed to run compressor (reading of energy meter);

$E = E2 - E1$

Coefficient of performance COP

$$COP = \frac{\text{cooling effect produced}}{\text{work consume to run compressor}}$$

3. OBSERVATION TABLE (SYSTEM WITHOUT PRE-COOLER)

Table 1. System without Pre-Cooler

Time and date	Energy meter reading in Kw.hr			Inlet air temperature		Outlet air temperature		COP
13/5/18	Initial reading E_1	Final reading E_2	Power consumed E_2-E_1	DBT	WBT	DBT	WBT	
8.51 a.m. 9.51a.m.	161.3	162.8	1.5	26	18	18	14	2.04
11.18a.m. 12.18p.m.	164.6	166	1.4	25.6	20	16.8	16	2.377

Table 1 show initial and final readings of energy meter and represents by $E_1$and E_2.window air conditioner runs for one hour. System runs without pre-cooler. Outlet air temperature and inlet air temperature of window ac is measured. DBT and WBT of outlet air and inlet air temperature are measured by sling psycho meter and COP is calculated.

Table 2. System with pre-cooler

Time and date	Energy meter reading in KWh			Inlet air temperature		Outlet air temperature		COP
13/5/118	Initial reading E_1	Final reading E_2	Power consumed E_2- E_1	DBT	WBT	DBT	WBT	
10:6a.m. 11:.6 a.m.	163.1	164.3	1.2	25.8	20	17	15	3.2
12.28p.m. 1.28 p.m.	166.2	167.5	1.3	25	21	17	16	3.15

Table 2 shows initial and final readings of energy meter and represents by $E_1$and E_2.window air conditioner runs for one hour. System runs with pre-cooler. Outlet air temperature and inlet air temperature of window ac is measured. DBT and WBT of outlet air and inlet air temperature are measured by sling psycho meter and COP is calculated. It has been noted that from both systems with and without pre-cooler, System with pre-cooler gives greater COP and reducing power consumption.

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Table 3. Observation table of Refrigerant Cycle

Sr. No.	system	suction pressure(P_1)	Delivery pressure	condenser temperature				evaporator temperature	
		P_1	P_2	T_1	T_2	T_3	T_4	T_5	T_6
1	without pre-cooler	4.6	24.2	80	48.9	46.7	18	12	23
2	with pre-cooler	4.1	20	70.8	36.9	16	14	9.5	22

Window air conditioner with refrigerant R-22 is used for this study. Table 3 shows the measured suction and delivery pressure of compressor, denoted by P_1 and P_2. To measure refrigerant temperature inside condenser coil four surface type temperature measuring sensors are attached on surface of condenser coil, which shows rated temperature of refrigerant flowing inside the condenser coil. They are represented by T1, T2, T3, T4 and evaporator temperature measured by surface type temperature sensors shown by T_5 and T_6.

Table 4. Comparing both Systems with Pre-Cooler and Without Pre-Cooler at Afternoon

Sr. No.	Without Pre-cooler		With Pre-cooler		Result in %	
Time	8:51am-9:51am	11:18am – 12.18pm	10:06am - 11:06am	12:28pm - 01:28pm	Morning	Afternoon
Work Consumption	1.5	1.4	1.2	1.3	20%	9%
Cooling effect produced	3.072	3.328	3.84	4.096	25%	23%
COP	2.04	2.377	3.2	3.15	56%	32%

Table 4 shows the collected data by modified system with pre-cooler at afternoon, where ambient air temperature is higher as compared to morning ambient air temperature reduction in power consumption is 9% and COP is 32% increase. While reading taken in morning 20% reduction in power consumption and 56% increase COP.

Conclusion:

Experiment results shows that new modified design with air pre-cooler reduces power comparison by 10% to 15% and increase COP of 30% to 40% at different outside weather condition.

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