Air Conditioning System with Modified Condenser Ducts and Evaporative Cooling

Dr. Akash Langde[1], Zeeshan Jamal[2], Shahrukh Jamal[3], Mohammad Shumoil Ansari[4]

[1]Professor, Department of Mechanical Engineering, Anjuman College of Engg. & Tech Nagpur, India
[2]Department of Mechanical Engineering, Anjuman College of Engg. & Tech Nagpur, India
[3]Department of Mechanical Engineering, ITM College of Engg, & Tech Nagpur, India
[4]Department of Mechanical Engineering, Sinhgad College of Engineering, Pune, India.

Abstract - *The performance of a refrigeration cycle can be increased by reducing the compressor work or by increasing the refrigeration effect. It was found through the literature that advancement in the design of compressor reduce the compressor work and also the advancement in the capillary tube increased the refrigerating effect. Modifications in condenser are meant to increase degree of sub-cooling of refrigerant which in turn increases refrigerating effect. The improvement in coefficient of performance and reduction of energy consumption of a window air conditioning system when retrofitted with ducts and evaporative cooling in the condenser of Window air conditioner is reviewed in the study. The condensing unit is fitted with evaporative air cooling unit. This condenser can exchange heat with the ambient air, cooled with evaporative cooling which is much lower in temperature than atmospheric air. By application of evaporative air cooling it is possible to ex-change more heat. A Window air conditioner is introduced by putting evaporative air cooler which includes the cooling pads system and injecting water on them in order to cool down the air before it passes over the condense. This paper presents the concept of effect of Under-cooling on the Coefficient of Performance of Vapor Compression Refrigeration System mainly carried out to improve the coefficient of performance of system.*

Key Words: **Window Air-Conditioning system, Dessert Air cooler, Modified condenser with ducts, Under-cooling, Coefficient of performance.**

1. INTRODUCTION

Energy consumption has become an important aspect when it comes to system optimisation. Energy costs and environmental concerns have made energy optimization a critical issue. Therefore, energy efficiency is the major aspect in reducing global warming emissions. In context to this, new technologies to conserve energy, to use energy effectively, to use alternative energy sources and to reduce the energy costs such as solar energy, wind energy, tidal energy etc. are under continuous development. This study shows theoretical and experimental studies of improved vapour compression refrigeration cycles capable of improving the efficiency of cycle and making it cost effective. The least expensive way of reducing operational costs in a system is to lower its energy consumption best done by increasing energy efficiency.

The improvement of refrigeration cycle performance can be done by reducing the compressor work consumption, increasing the condenser heat rejection capacity or reducing the difference between condenser and evaporator pressures. Because of its simplicity and compactness window air conditioner is generally used in small size in residential and commercial buildings. The condenser used in this system for heat rejection process which is generally air cooled, it seems reasonable as far as the air temperature in summer is moderate and not too high (about 45º C). But when the air temperature increase and approaches 50º C or higher Window air conditioner that consist of two parts fan coil unit and condensing unit gives poor performance. The performance of window air conditioner depends on heat transfer between the condenser coils and the airflow. Hence by cooling ambient air temperature by evaporative cooling could results in substantial energy and demand saving, this small saving could save considerable amount of watts unit. In air conditioning system generally there are three types of condensers using air cooled, water cooled, and evaporative cooled. Condensers used in small residential Window air conditioners are mostly air cooled condenser.

Changes in condenser to improve coefficient of performance refers to increase degree of under-cooling. The evaporative cooler is retrofitted in front of air-cooled condenser to pre-cool outdoor air before entering the condenser. The pre-cooled air is carried through the duct to the condenser. Tests were carried out and results were predicted that the use of the evaporative cooler results in an increase in the refrigeration effect.

2. WORKING PRINCIPLE

If unsaturated air is passed through a spray of continuously re-circulated water, the specific humidity will increase while the dry bulb temperature decreases. This process is called adiabatic saturation or evaporative cooling.

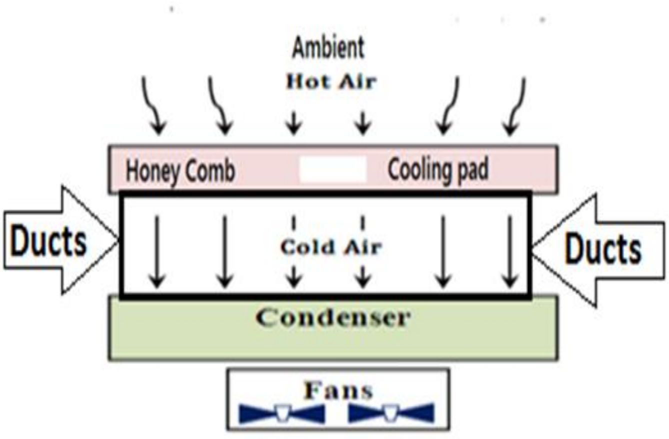

Fig-1: Working Principle.

Air cooler pumps water on the evaporative honey comb cooling pad which is kept in the way of air over the condenser and provides cooling effect by evaporation of water. This provides the cooled & humidified air. This cooled & humidified air flow over the condenser surface by forced draft fan. The place of air cooler should be installed in a way to give a good cooling effect and also takes minimum space from out-side partition of our equipment

3. EXPERIMENTAL SETUP AND COMPONENTS

- Window A.C.
- Dessert Air Cooler.

3.1 Window A.C

Window Air-Conditioner selected for the project has the following specifications:

Refrigerant used: R-22
Capacity of the AC: 1TR
Compressor capacity: 1HP

The suggested window air conditioner consists of 4 major parts they are as follows:

- Compressor (operating pressure limits 3 to 15 bars).
- Expansion device (Capillary Tube).
- Evaporator.

3.2 Modified Condenser with Ducts

The functions of the condenser are to cool the high pressure gas, condense it and also sub-cool the liquid. Heat from the hot refrigerant gas is rejected in the condenser to the condensing medium air. Air is chosen because they are naturally available. The normal temperature range is satisfactory for condensing refrigerants.

Air movement over the surface of condenser tubes is by natural convection. As air comes in contact with the warm-condenser tubes, it absorbs heat from the refrigerant and thus the temperature of the air increases. Warmer air being lighter rises up and cooler air replaces it from below to take away the heat from the condenser. This cycle goes on. Since air moves very slowly by natural convection, the rate of flow of heat from the refrigerant to air will be small. Thus a natural convection condenser is not capable of rejecting heat rapidly. Therefore a relatively large surface area of the condenser is required.

Advancements in condenser in order to increase the coefficient of performance can be achieved by increasing degree of sub cooling. This is done by the use of direct evaporative cooler to improve the energy efficiency of air-cooled condenser. The evaporative cooler is installed in front of air-cooled condenser to pre-cool outdoor air before entering the con-denser. The pre-cooled air is carried to the condenser through ducts. These ducts are thermally insulated from inside and arrangements were made to make the assembly air sealed.

3.3 Desert Air Cooler

The principle of working of a desert cooler is 'Evaporative cooling'. Evaporative cooling is a process in which the sensible heat is rejected and moisture is added to the ambient dry air. When dry air is passed through a spray of water or cooling pad, it rejects heat to water, some of water evaporates and picks up heat from the air equivalent to the latent heat of air. The vapors thus formed are taken along in air stream. In this way air is cooled and humidified.

The water is filled in the sump of the cooler from water supply tank. Water pump create suction and lifts the water to supply it at the top of the cooler to the water distribution system which consist of small branches of pipes or so equipped with orifices which deliver equal amount of water to the toughs which in turn supply water to the wetted pads. The water which drops back on the pad is recirculate.

The blower fan drags the air through the moist pads and delivers it to the space to be cooled through an opening in the fourth side of the cabinet of desert cooler. The air which is pulled through the pads is cooled by the principle of evaporative cooling. The blower gives considerable velocity to the air before it is delivered to the space to be cooled.

In this setup the air cooled by the pads of the desert cooler is carried to the condenser through retrofitted ducts. Provisions were made to seal the blower opening of the desert cooler to make sure only cooled air from wetted pads goes to condenser. Hence only pre-cooled air was supplied to the condenser. The experimental setup can be seen in fig-2. Showing Window AC assembled over desert cooler.

Fig-2: Experimental setup.

4. OBSERVATIONS

The following tests were carried out in the laboratory of Anjuman College of engineering and technology, Nagpur India during mid-daytime in the month of March (summer). The lab was sealed with plastic curtains to prevent heat dissipation into the room from the surrounding. Other heat radiating machines were also removed from the lab. The condenser ducts were also insulated with thermal insulation lining. The following arrangements were done to achieve least amount of variation during the test.

The tests were conducted under two sections;

- Without evaporative cooling.
- With evaporative cooling.

Readings were recorded at an interval of 5 minutes and the data was tabulated.

4.1 WITHOUT EVAPORATIVE COOLING

The window AC was run on conventional cycle (i.e. without evaporative cooling). Data recorded is tabulated as under in Table -1.

Table -1: Observation table (without Evp. Cooling)

Time. (mins)	Room Temperature (T_r) °C	Evaporator outlet temp. (T_1) °C	Condenser inlet Temp. (T_2) °C	Condenser outlet temp. (T_3) °C	Evaporator inlet Temp. (T_4)	COP
5	30.2	31.1	58.9	39.6	25.4	4.46
15	28.5	19.2	80.9	40.1	29.5	2.86
25	28	18.4	84.7	40.3	31.2	2.72

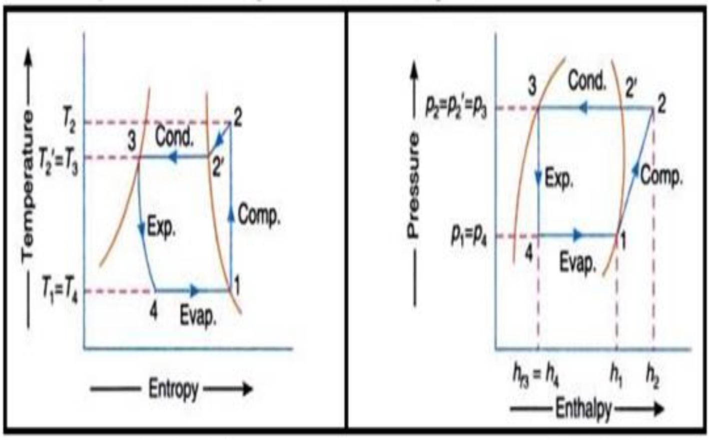

Fig-3: T-S and P-H diagram without under-cooling.

4.2 WITH EVAPORATIVE COOLING

After recording the observation without evaporative cooling of the air, the pump supplying water to the pads was operated and temperature readings were recorded between time intervals of 5mins. Following observations are recorded in the Table-2 given below.

Table -2: Observation table (with Evp. Cooling)

Time. (mins)	Room Temperature (T_r) °C	Evaporator outlet temp. (T_1) °C	Condenser inlet Temp. (T_2) °C	Condenser outlet temp. (T_3) °C	Evaporator inlet Temp. (T_4)	COP
5	29.9	26.2	57.9	34	20	4.9
15	29.2	21.3	70.3	35.7	23.2	3.6
25	28.2	19.4	73.9	35.2	23.5	3.43

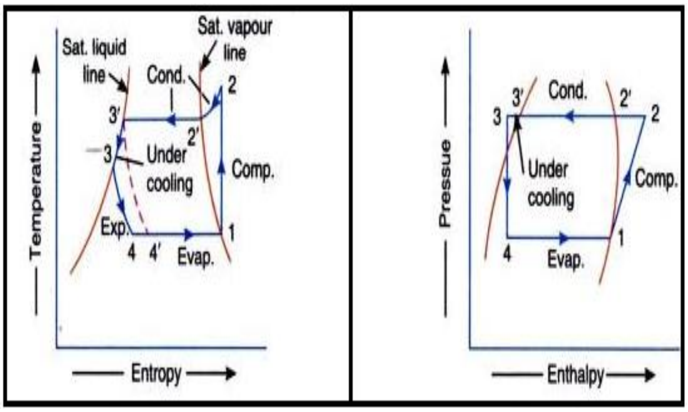

Fig-4: T-S and P-H diagram with under-cooling.

5. RESULTS

The results of COP for the simple conventional refrigeration cycle and cycle with modified condenser ducts for evaporative cooling is shown in the chart given below. It is clear that the COP is increased.

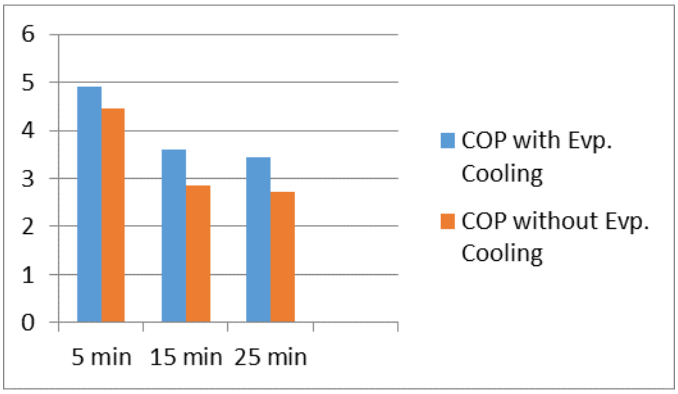

Chart-1: Time VS COP chart.

The condenser outlet temperature for both the cycles is shown below;

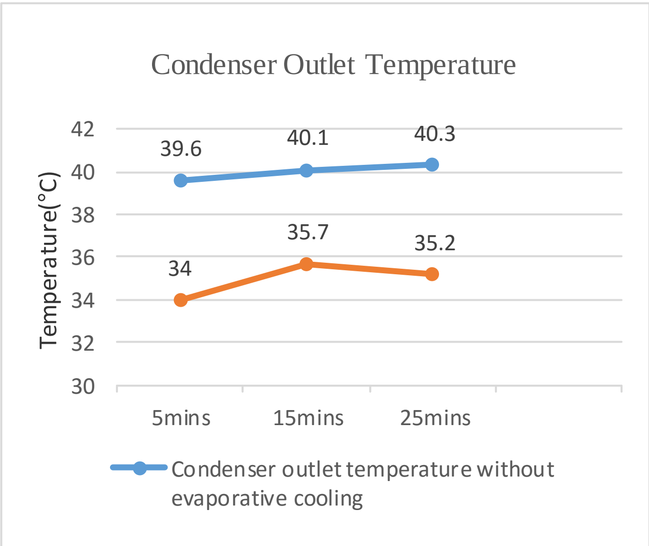

Fig-5: Condenser outlet temperature.

6. CONCLUSIONS

1. The experimental results revealed that with evaporative cooling system, the cooling capacity and coefficient of performance increased considerably.

2. The cooling-down of air for condenser caused by its interaction with the cooling pad water is much better than during the conventional flow around the condenser tube.

3. The pressure of condenser and evaporator reduces.

4. By sub-cooling enthalpy of vaporization of refrigerant increases, so refrigerating effect increase thus COP increases.

5. COP of Vapor Compression Cycle is increased by increasing the refrigerating effect. The heat transfer will increase due to increase in pressure and temperature.

Hence, there will be reduction in size and cost of the condenser.

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BIOGRAPHIES

Prof, Dr. Akash Langde.
Anjuman College of Engineering and Technology, Nagpur, India.
Nagpur University.

Zeeshan Jamal.
Student of B.E
Anjuman College of Engineering and Technology, Nagpur, India.
Nagpur University.

Shahrukh Jamal.
Student of B.E
ITM College of Engineering and Technology, Nagpur, India
Nagpur University.

Mohammad Shumoil Ansari.
Student of B.E
Sinhgad College of Engineering,
Pune, India.