EXPERIMENTAL INVESTIGATION OF PERFORMANCE OF EVAPORATIVE COOLING SYSTEM BY OPTIMIZING THE THICKNESS OF EVAPORATIVE PAD

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CERTIFICATE

I hereby certify that the work which is being presented in the Dissertation-II entitled **"Experimental investigation of performance of evaporative cooling system by optimizing the thickness of evaporative pad"** in partial fulfillment of the requirement for the award of degree of **Master of Technology** and submitted in Department of Mechanical Engineering, Lovely Professional University, Punjab is an authentic record of my own work carried out during period of Dissertation II under the supervision of **TALIV HUSSAIN** (**17727**) Department of Mechanical Engineering, Lovely Professional University, Punjab.

The matter presented in this dissertation has not been submitted by me anywhere for the award of any other degree or to any other institute. .

Date: April 29, 2015 **(GOURAV ROY)**

This is to certify that the above statement made by the candidate is correct to best of my knowledge.

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Signature of Examiner

Abstract

Abstract-The main aim of this paper is to analyses the performance of vapour compression refrigeration system .In last several decades many improvements has seen for vapour compression refrigeration system. In order to increase the efficiency, one possible means is to increase the COP of the system. So, experimental investigation of performance of evaporative cooling system is studied by varying the thickness of evaporative cooling pad at same ambient temperature and at different ambient temperature by using R134a as a refrigerant so as to get maximum COP. A vapour compression refrigeration system has been built with evaporative cooled condenser. In first case evaporative cooling pad of thickness 7cm and 15cm is used at ambient temperature 31°C.There is increase in COP 0.06 by using 15cm thickness pad. Similarly in second case evaporative pad of thickness 7cm and 15cm is used at ambient temperature 33°C.There is increase in COP 0.2 by using 15cm thickness pad. Also comparing the COP at different ambient temperature 31°C and 33°C.There is decrease in COP 1.6 from 31°C to 33°C by using 7cm thickness pad. Similarly, there is decrease in COP 1.45 from 31°C to 33°C by using 15cm thickness pad.

Keywords-Evaporative cooled condenser, vapour compression refrigeration system, evaporative cooling pad.

Nomenclature-COP Coefficient of performance

h_1 Enthalpy of refrigerant at inlet of compressor in kj/kg

h_2 Enthalpy of refrigerant at exit of compressor in kj/kg

h_3 Enthalpy of refrigerant at exit of the condenser kj/kg

h_4 Enthalpy of refrigerant at entry of evaporator in kj/kg

m_{ref} Mass flow rate of refrigerant

Q_r Cooling effect

W_c Compressor work

T_1 Suction temperature of refrigerant into the compressor

T_2 Discharge temperature of refrigerant into the compressor

T_3 Condenser outlet temperature of refrigerant

T_4 Outlet temperature of refrigerant from capillary tube

I Inlet current

V Inlet voltage

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1. INTRODUCTION

1.1 General overview

The issues like global warming, the natural resources depletion, and demand for environmentally-friendly systems have led to the growth in use of natural green resources instead of conventional systems unit. Cooling is the best energy-intensive method for air conditioning and ventilation process. Compressor cycle which is one of the best traditional unique systems mostly based on above cycle, which takes too much energy. Compressor circuit which contained refrigerant due to which it damages the overall environment.During 1834 the first mechanical device cooling system have been develop later it become vapour compressor.Residential air conditioning has become common and which is increase in all over the United State over last 30 years in order to provide comfort demand. In 2009 Residential Energy Consumption Survey (RECS) show that 61% of residential homes have central air conditioning. This is up significantly from 47% in 1997 and only 23% in 1978.Also it has seen that during summer there is peak electricity demand is being used by the propagation of Refrigeration and Air conditioning appliances.

In hot summer climate condition, evaporative cooling process is more effective and economical technique of cooling system. Due to increasing in environmental pollution and depleting of energy resources, now a day attention of all researchers shifted toward the alternative cooling systems. Air conditioning system has become popular not only for human but also to provide comfort environment for animal and plants also. Due to which it consume large amount of energy. For that reason in air conditioning application evaporative cooling is best alternative as compare to mechanical vapour compression .In mechanical vapour compression electric power consumption is more where as evaporative cooling only require quarter of electric power as compared to the mechanical vapour compression. Therefore it contributes to reducing greenhouse gases and also helps to reduce electricity consumption. The fruit of development would not reach to the common man until energy reached the last household of the country. In RAC the special focus is given on VCRS system to improve overall performance and cooling capacity of a system. To accept anything without testing or without knowing and trail, the capacity to change previous conclusion in the face of new evidence, the reliance on observe fact this all is necessary. Special emphasis will be placed on equity in development of VCRS system, so that the benefit of technological growth reaches the majority of population, leading to an improved quality of life forever citizen of country. In

Evaporative cooler the above factor helps in active development. As compare to normal traditional compressor refrigeration system, normal air cooler in home on evaporative cooling take very less amount of energy. Truly they help to make ecological and environment based system. On the state of air, the overall COP of evaporative air system is depending. For this system the best condition is during the hot day and dry climate environment. Air WBT is the determining factor. Evaporative cooling provides a low-cost, energy efficient and environmentally suitable method of cooling.

The procedure of evaporative cooling has been used to improve human, plants and animals comfort conditions for the long time in the thermal environmental control applications. It is a reliable method and requires minimum power consumption. Liquid state to gaseous state takes place during evaporation. During hot days, we feel cool when a nice breeze of air helps in perspiration evaporation suddenly. The water gets evaporate when air is passes over the water surface. Heat is one of the necessary requirements for water to gets evaporates. The great example which implies that during ancient time there is also a concept of evaporative cooling exists. One of the famous architect belonging to Egypt name Hassan Fathy's. They used earthen pots which having porous in it and which is filled with water in it. It's a kind of vertical shaft whose one face is open to the wind and another to the ground level. This method used in fountain which is placed in Persian garden. Now sprayed water from above vertical shaft helps in air to cools down. ECS system is mostly seen in country where the overall environment is very hot climate and dry weather. It is mostly seen in Australia and India. 74% of overall p.e is saved when we replace normal refrigeration system by ECS system.

In this project we have concentrated our study toward the evaporative cooling condenser. Evaporative cooling condenser in vapour compression system has some special advantage in order to increase the performance. Such as using Cellulose pad in evaporative cooling condenser which affects the performance of vapour compression system and by varying the thickness of Cellulose pad, performance varies. Also Cellulose pad are easily available and cheap cost. When the thickness of Cellulose pad increase COP increase at both the ambient temperature 31°C and 33°C and COP decreases from 31°C to 33°C by same thickness of Cellulose pad.

1.2 Basic Components

A schematic vapour compression air conditioning system is shown in Fig.1.1. It consists of a compressor, a condenser, an expansion device for throttling and an evaporator.

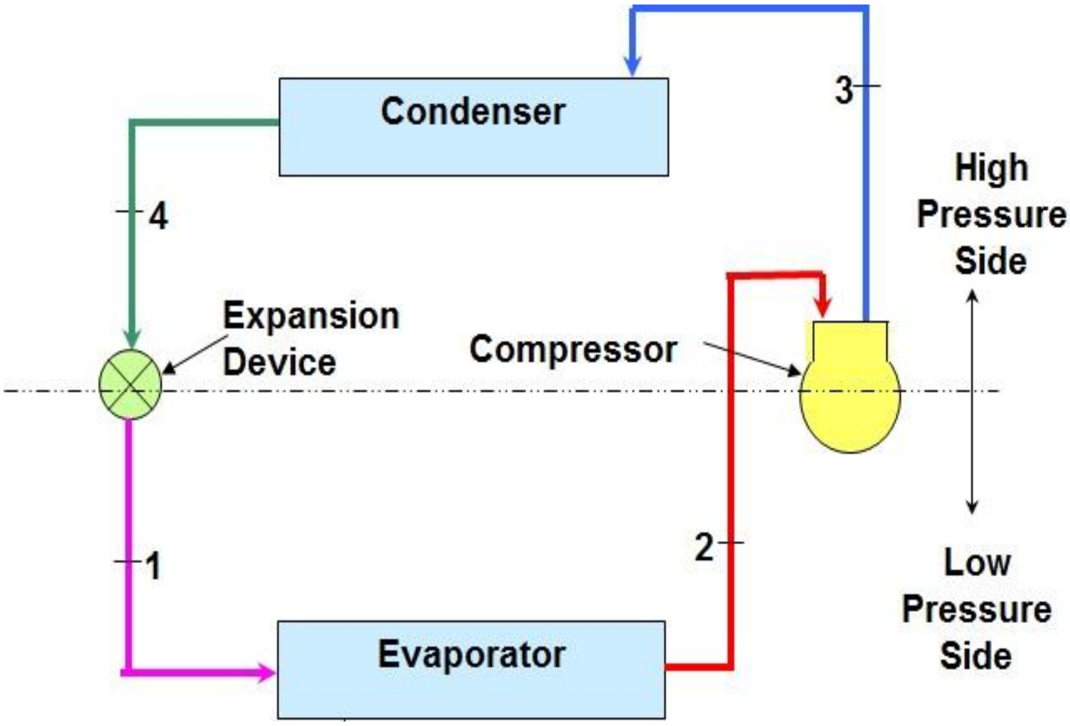


Fig. 1.1 A simple vapour compression refrigeration system

In Freon system which has liquid line in which drier system is also placed. The amount of moisture that is in liquid refrigerant is absorbed by silica gel present in drier. So we prevent the moisture chocking while it not enter into expansion device unit. Sometimes, oil separator are also installed after the compressor which separates the lubricating oil from the refrigerant before going into the condenser and returns it into the compressor.

1.2.1 Compressor

The compression of the vapour refrigerant from the evaporator to the condenser pressure can be achieved by mechanical compression, ejector compression or by a process combination of absorption of vapour, pumping and de-sorption.

The hermetically sealed compressor is widely used for the refrigeration and air conditioning applications. In this compressor, motor is placed in a welded steel casing and the two are connected by a common shaft. It makes the whole compressor and the motor as a single compact and portable unit that can be easily handled. Fig. 1.2 shows the cross section view of a HSC.

Fig. 1.2 Cross section view of HSC

1.2.2 Condenser

Condenser is an important component of any refrigeration system. In a refrigerant condenser, the refrigerant enters the condenser in a superheated state. First initially de-superheated which takes place in the discharge line and in the first few coils of the condenser and heat is rejected to the external air or water medium further it helps in condensed. From the exit of condenser the given refrigerant is sub-cooled liquid or saturated. Mostly the above condition is depending upon the external air or water which is used as medium; also depend upon tube and fin of condenser. However, the sensible heat of the sub-cooling and de-superheating is very small as compared to the latent heat of the condensation process.

Based on the external fluid, condensers can be classified as:

a) ACC

b) WCC

c) ECC

1.2.2.1 Air Cooled Condensers

In ACC air act as external medium fluid, i.e., the given R134a eliminate its heat to medium that is air which passes through ACC. ACC divided into two categories:

a) NCT

b) FCT.

1.2.2.2 Water Cooled Condensers

In water cooled condensers water is the external medium fluid. On the basis of construction, water cooled condensers divided into two categories:

a) DP or TITP
b) ST and CT
c) ST and TT

1.2.3 Expansion Device

An expansion device in a refrigeration system normally serves two purposes. One is the thermodynamic function of expanding the liquid refrigerant from the condenser pressure to the evaporator pressure. The other function is to control which involves the supply of the liquid to the evaporator at a rate of its evaporation. The latter has an important role and determines the efficiency with which the evaporator surface is utilized. An expansion device is essentially a restriction offering resistance to flow so that the pressure drops, resulting in a throttling process.

Basically expansion devices are of two types:

a) Variable restriction type.
b) Constant restriction type.

In the variable restriction type, due to type of control the extent of opening keeps on changing. The control devices are mainly into two categories; the AEV and the TEV. AEV is not suitable for a varying load requirement. When the load decreases, diminishes vapour formation, and due to the compressor continues to suck the vapour there is evaporator pressure drops. As a result, the valve opens more and allows more refrigerant to enter the evaporator, so that the pressure remains constant, due to which there is flooding into the evaporator and thus superheat goes on decrease. It is mostly used in applications for example such as milk coolers where the precise control of the evaporator temperature is needed and where the cooling load is more or less remains constant.

The thermostatic expansion valve as opposed to the automatic expansion valve is capable of meeting varying load requirements. The systems which have thermostatic expansion valve the evaporator pressure and hence the evaporator temperature, do not remain constant. It keeps the evaporator always full of the refrigerant, regardless of changes in the cooling load. Even under extreme loading conditions this ensures the full utilization of the evaporator surface and the safety of the compressor (by not allowing the liquid to enter it) under part-load conditions.

The overall difference in pressure at the both the two end is equal to the pressure drop cumulative. The difference in pressure between the condenser and the evaporator is just equal the pressure drop through the tube where the mass flow through the capillary tube will adjust.

For the given condition of the refrigerant, the pressure drop is directly proportional to the length and inversely proportional to the bore diameter of the tube.

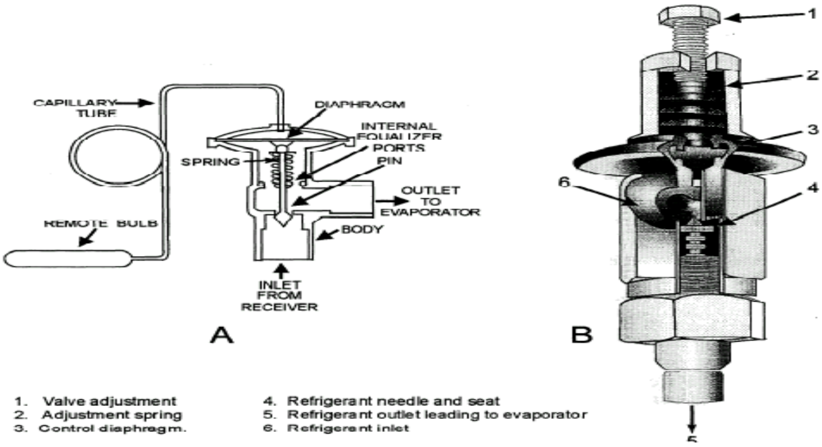


Fig. 1.4 Thermostatic expansion valve

1.2.4 Evaporator

The evaporator is the component of a refrigeration system in which heat is removed from given body, air or water required to be cooled by the evaporating refrigerant. Evaporators are mainly classified as dry and flooded evaporators. In dry evaporators, a part of heat transfer area is used for superheating the vapour and they use thermostatic expansion valve (in the case of large units) or a capillary tube (in the case of small units) for the expansion of the refrigerant. In flooded evaporators, the entire heat-transfer surface area is covered by liquid refrigerant and they use a float valve for the expansion of the refrigerant.

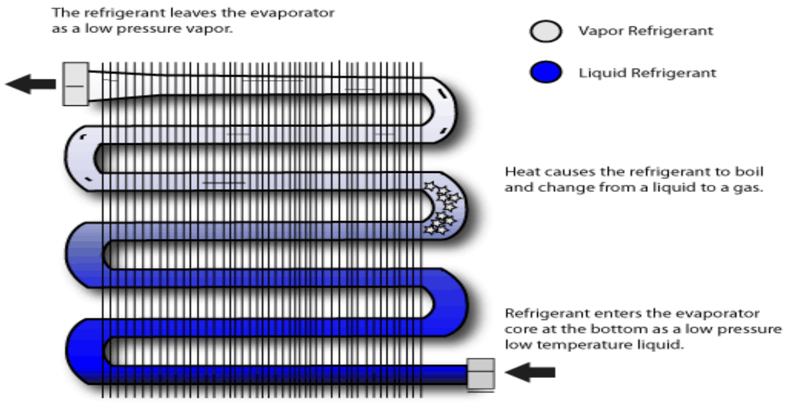


Fig. 1.5 Evaporator

1.4.1 Features of Evaporative cooling pads

• Evaporative Cooling Pads will not sag, rot or develop holes.

• By using proper maintenance and care, Evaporative Cooling Pads will last for 5 years.

• No carry-over of the water drop to enter into the house.

Fig. 1.9 Cellulose Pad

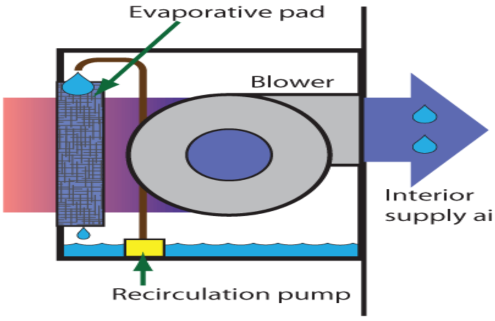


Fig. 1.10 Cooling effect using cellulose pad

1.4.2 Reason to choose EC.

- **Economy concern:**

1) In EC we not use cooling towers while used at water condenser. The overall expenditure in operating and acquisition is very less of wcc.
2) Initial cost is less and the operating cost is not too much as compared to air condenser system. Expenditure on maintain is not high and it also not require very less skilled maintenance.

- **Effective:**

3) Increased Comfort:

It LET- the temperature which we feel-it almost varies from 4oC to 6oC. On the basis of RH the temperature gets decrease. Continuously movement of air which is very cool passes from skin surface further help to increase in heat losses from body. According to ASHRAE Handbook, 1995, Ch-47 Explain….. "dbt reduction due to the…….LET RH level"….RC. of factor IS provided by evaporative cooling almost regardless of geographical location." ? Increased Comfort: In a large number of industries it is seen that mostly in hot weather to experience increased heat related problem such as illness and unconsciousness, increased absenteeism among workers and lower productivity. While evaporative cooling is much more effective. From the ASHRAE Handbook, 1995, Ch-47 Explain, EAC "EC can remove this heat related problem and help to increase the efficiency of labour with increase in morale value.

- **Health & Environment Benefits:**

Evaporative cooling is comfortable and healthy mainly for following reason:

1) It helps to enter fresh atmosphere environment air which is initially cooled down and washed with help of filter cellulose pad

2) EC is increase with the help of movement of air. It’s not too much bulky.

3) EC not has a structure of airtight in order to achieve higher COP.

1.5 VCRS System principle and working

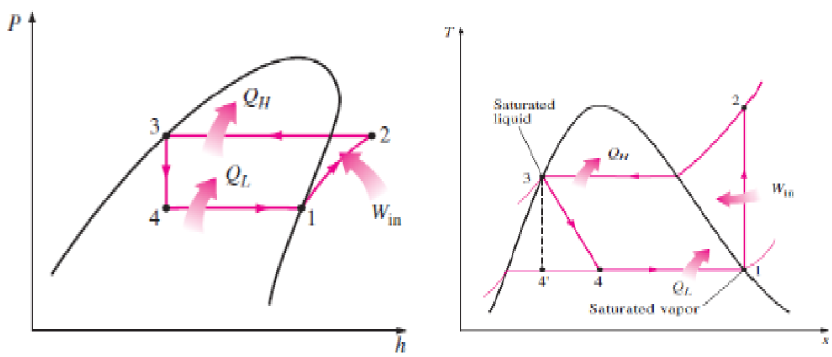
RS is depending on the 2nd law of thermodynamic. It says that impossible to design a system that can operate in a cycle and while transferring of heat from cooled body to hot body there will be no other effect rather than above. A VCRS system is commonly seen in HR system and F system. In above cycle system, the R134a which passes in overall close path .Firstly it goes at LP Vapour at compressor or temperature of R134a is more as compared to evaporator. Now vapour in C system initially compressed and out as HPS vapour. After that the SH vapour goes into circular long tube with certain pressure i.e. condenser and now R134a in condensing unit gets cooled down with the help of condensing medium that is present in room. Now condenser unit decrease the temperature of R134a vapour, which convert and become condensed. Now R134a at the exit of condenser unit, but it maintain is pressure and its temperature high. After passing from condenser unit it enter in EV which measure the proper amount of R134a, So that proper expansion process will take place LP. Due to pressure drop in SP, finally result in form of FE after passing from EV partially vaporize and CR passes through the EV of VCRS system. Finally Evaporation processes take within EV

Process 1–2: IC in compressor.

Process 2–3: CPHRP in condenser.

Process 3–4: IEP in expansion device.

Process 4–1: HAP in evaporator.



P-h diagram   T-s diagram

Fig. 1.11 Representation of VCRS on property chart.

1. LITERATURE REVIEW

Many experiments have been carried out. AR and CR also take place in order to improve the COP of AC system. Below there is brief literature survey is going to present related to EC condenser.

S.D.White et al. [1] in this work aims to develop a system which requires less floor area, increase the evaporation rate and to recover the fresh water from the water evaporated from the effluent. The system works on the principle of simultaneous HAMT take place in air and soak liquor in the spray tower leading to evaporation of water in soak liquor. Studies are carried out to utilize the heat rejected from the condenser of the VCR system to increase the temperature of the soak liquor. The hot soak liquor can be sprayed in the enclosed chamber to enhance the contact area between the soak liquor and air. Thus, both the process will contribute for increase in the evaporation rate compared to the conventional method. Moreover in present situation there is more scarcity for the availability of water. It will be useful if we recover fresh water from the above evaporation process. Efforts are made to recover the fresh water from the above evaporation process using the cooling load available in the evaporator of the VCR system.

Chan et al. [2] described the EE of DEC of ACC is used to increase by using variable different condition also with help of different position of fan condenser. In this fan is placed behind the ACC in order to precooled the atmosphere air while entering into the c unit.

By using with the help of direct evaporative cooler, due to which compressor power dropped down and there is decrease in the condensing temperature in most of favorable conditions, while there is pressure drop across the cooler take place caused additional condenser fan power consumption. The total saving of chiller power varies from 1.4% to 14.4%.

Sethi et al. [3] the evaporative cooling of greenhouses is based on the evaporation of the water in the mass of warm incoming air enter, thus allowing a drop in temperature and rise in the humidity content of the air. It can be achieved by directly spraying water inside the greenhouse and combining it with natural ventilation or by forcing the incoming air to pass through dampened evaporative pads and installing fans to ventilate the greenhouse artificially (pad-fan cooling systems).

Wu et al. [4] proposed a simplified cooling efficiency based on the energy balance analysis of air to analyze the heat and mass transfer between air and water film in the direct evaporative cooler. The analysis showed that the frontal air velocity and thickness of the pad module are two key factors influencing the cooling efficiency of a direct evaporative cooler.

Eghtedari H. et al. [5] investigated about the uses of ECAC as compare to ACC to solve the problem of maintaining higher COP in hot weather conditions. Finally he built an evaporative cooler and joined it with same AC of SAC .So that they get higher COP of the system. While performing the experiment they get higher COP increase and cooling rate high in ECAC as the outside air temperature rise.

Kachhwaha and Suhas [6] designed, fabricated, and predicted the performance of an evaporative medium. The pad thickness and height were achieved for maximum cooling.

Datekin et al. [7] Examine the overall effect of velocity of the air on it temp. and CE. Finally result shown tells that velocity of air drop in temp. of air and CE. While it has no mathematical formula generated. His results explain velocity of air changes from 0.5m/s to 1.5m/s while performing the experiment.

Franco et al. [8] explain the different parameter which is a function of velocity of air by using ECP in WT. He finds out that PD, the velocity of air, velocity of water and consumption of water by CP. He finally concluded that SE varies from 64% to 70%

Kulkarni and Rajput [9] Calculate COP theoretical of I/D two stage C system with CP and AM in DS. They have ambient temperature 39.9^{o}C dbt and 32.9 % of RH. finally they get 121.5% to 106.7% of S.E

Yang et al. [10] investigated about application of mist evaporative precooling to air cooled chillers. The experimental results showed that the dry bulb temperature of entering condenser air with water mist pre-cooling could drop up to by 9.40 ^{o}C from the required ambient air temperature. The 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.

Adarsh Mohan Dixit et al [11] presents an experimental investigation of a high-efficiency air conditioner that utilizes cellulose pad before the condenser. The heat and mass transfer characteristics of the cellulose pads is first studied and the results are used for the design of the air conditioner. A 1.5 ton air conditioner was constructed and tested in the current study. The experimental results show that the coefficient of performance (COP) reaches 8.03 that are higher than that of standard value (5.98) of those conventional residential split air conditioners.

V. V. Birangane et al. [12] studied that the performance improvement of Air cooled condensers can be achieved by using evaporative cooling method. This method may show quiet effective and less costly. There are many researchers working on the above parameter. Few of them have successfully implemented the research in practice.

4. SCOPE OF STUDY

Air conditioning systems used for domestic and industrial purposes use air cooled condenser in which compressor consumes a lot of power. Due to high ambient temperature COP of the system also decreases as high ambient air temperature reduces the heat rejection rate from the condenser. Thus the refrigerants do not fully convert into liquid state after the condenser which further decreases the refrigeration effect at the evaporator.

So the COP of the air conditioner can be improved by lowering the compressor power consumption, increasing the cooling and heat rejection capacity or by reducing the pressure difference between the condenser and evaporator unit system. Decreases the pressure difference between the condenser and evaporator is the fruitful one in comparison with those mentioned above.

While always the evaporating temperature is always kept constant and lowering down the condensing temperature which shows a result in the reduction of pressure difference. This reduction in the condenser temperature can be done by evaporative cooled condenser. The pressure difference between the evaporator and the condenser reduces to a great extent by using evaporative cooled condenser. High heat rejection is also possible in case of evaporative cooled air conditioning systems as compare to air cooled air conditioning systems.

5. OBJECTIVE OF STUDY

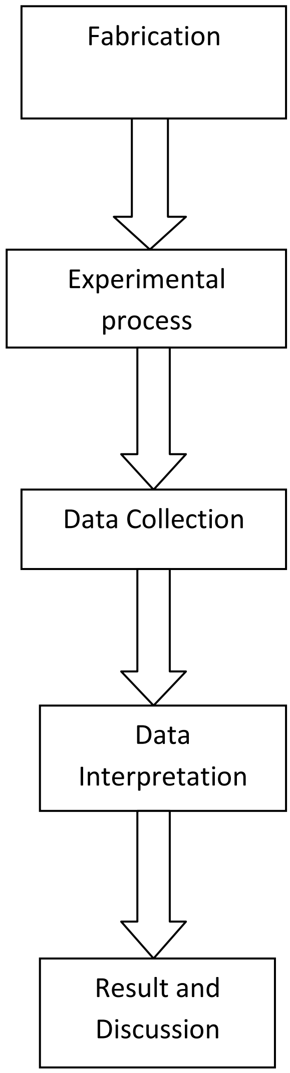
- Experimentally investigation of performance improvement in the COP and the power consumption of the Evaporative cooled air conditioning systems (EACS).
- To study the variation in the Thickness of Cellulose Pad which effect the performance of Evaporative cooled air conditioning systems .

6 .RESEARCH METHODOLOGY

The experimental setup consists of a single stage vapour compression system with the basic components i.e. evaporator, compressor, expansion device and condenser. A frame is to be manufactured and covered it with the help of CMP and is placed them before the ACC unit.

With help of small watt pump is used in order to provide water over th CP. It placed in bucket whose one end placed at the top of CP. Flow of water will remain constant. When outside air passes from the EMP and cooled down further it enter into yhe condenser unit. Ammeter and Voltmeter is used to determine the EC and EV of input power respectively.

The bourdon pressure gauges are used to be measure the inlet and outlet pressure of compressor. Temperatures of refrigerant and circulation air at different points are recorded with the help of thermocouples. Insulation tapes are placed over the copper tubes to provide better contact and also prevent any convection effect of ambient air on the temperature readings.



7. EXPERIMENTAL SETUP

In the present work we have concentrated toward the thickness of cellulose pad that is used in evaporative cooled condenser. Here cellulose pad are used to cool down the air which is further used to cool down the condenser. The COP change from 7cm thickness pad to 15cm thickness pad and also the COP varies with varies with ambient temperature 31°C to 33°C.

In the experiment setup (figure7.1) consist of single stage vapour compression system which contains different components parts such as expansion device, compressor, evaporator and evaporative cooled condenser. The compressors of volume (cc) 4.5 are used to increase the press. and temp. of (R134a).Here the capillary tube is used, made up of a copper tube of very small diameter 0.36mm.Capillary tube used as expansion device. The evaporator is used to reduce the pressure, dissipating heat and making liquid refrigerant to much cooler. Evaporator used in this experiment setup is tube and fin type. At an ambient temperature air enter horizontal through cellulose pad (figure 7.2), whereas pumped water flow continuous vertically over the cellulose pad with the help pump of 18 watt. Flowing of water continuously circulate over the cellulose pad while performing the experiment.

Different measuring devices are used in this experiment setup such as Digital Thermometer TPM-10, which gives the temperature at various points within the system. Pressure gauge is also used; first pressure gauge measures the suction pressure before the compressor and second pressure gauge measure the discharge pressure after the compressor. Similarly ammeter and voltmeter are used to measure the current and voltage to input to the system.

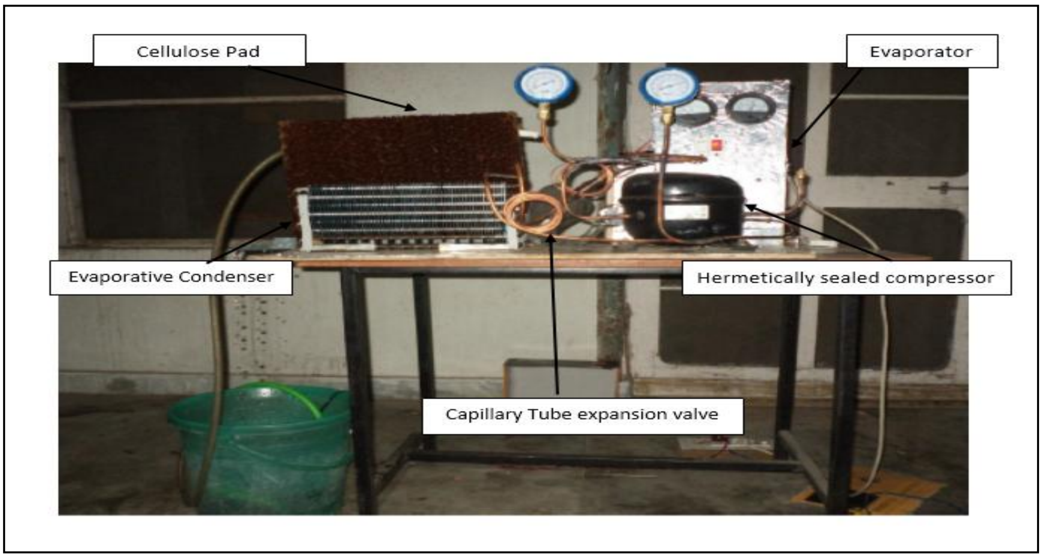


Figure 7.1: Experimental setup with evaporative cooled condenser

7.1Major component

The evaporative cooled condenser is cooled by the evaporative action of falling water which takes up the latent heat of ambient air .This cool ambient air then passes through the condenser. Table 7.1 gives the geometric data of the condenser.

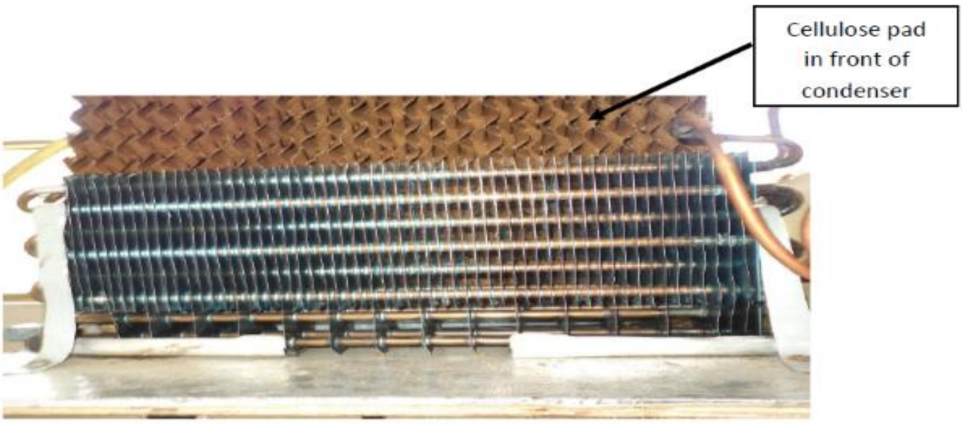


Figure 7.2: Cellulose pad used in evaporative cooled condenser

Number of pass	16
Inside diameter of tube (m)	.008
Outside diameter of tube (m)	.01

Table 7.1: Geometric Data of the condenser

The compressor used in this experimental setup is hermetically sealed type of LG. In this type, the shaft of the compressor is directly coupled to the motor which is mounted on the same base and this complete system is enclosed in the housing as shown in Fig 7.3. In the compressor, low press. and low temp. vapour from the Ev unit enters through the suction line and the high pressure and high temperature vapour leaves from the discharge line. This type of compressor gives minimum noise, since vibration in the system reduces due to mounting of the compressor and motor on the same shaft. Table 7.2 gives the technical detail of the compressor.

Compressor type	Hermetically sealed
Weight	8.3
Volume (cc)	4.5
Volt	220V
Frequency	50 Hz

Table 7.2: Technical details of compressor

Figure 7.3: Hermetically sealed compressor

When the refrigerant leaves the condenser and enters the capillary tube its pressure drops down suddenly due to frictional resistance offered by the tube walls. The capillary tube which is used in experimental setup is shown in Figure 7.4.

Figure 7.4: Capillary Tube

When the liquid refrigerant enters the evaporator its pressure has been decrease due to which it dissipating its heat related content and making it much cooler than the air flowing around across it. Due to this it causes the refrigerant to absorb heat from the surrounding warm air and to reach its low boiling point continuously. Now then the refrigerant vaporizes, and absorbing the maximum amount of latent heat from surrounding air. This heat is then carried by the refrigerant from the evaporator as a low-pressure gas through a hose to the inlet side of the compressor. The evaporator removes heat from the region which is to be cooled. Table 7.3 gives the dimensions of tube used in evaporator.

Number of turn	16
Inside diameter of tube (m)	.009
Outside diameter of tube (m)	.01

Table 7.3: Geometric Data of the evaporator

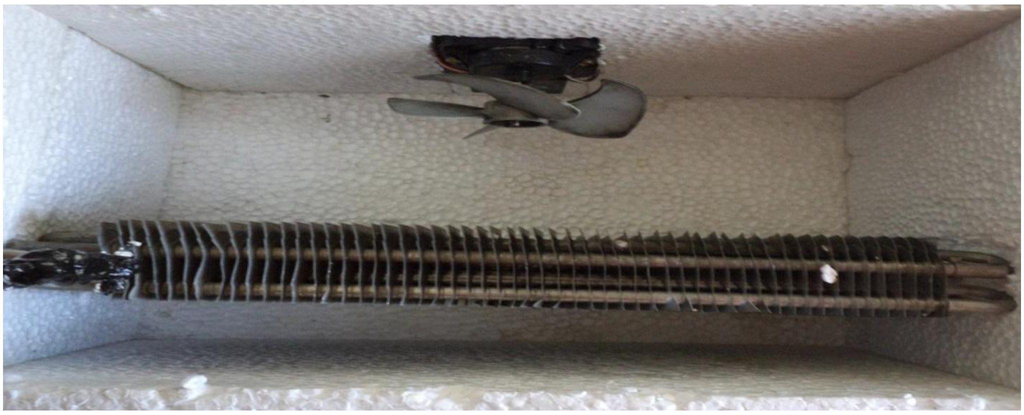


Figure 7.5: Evaporator coil

A small water pump of 18 watt is used for the continuous circulation of the water. The mass flow rate of water remains constant throughout the process.

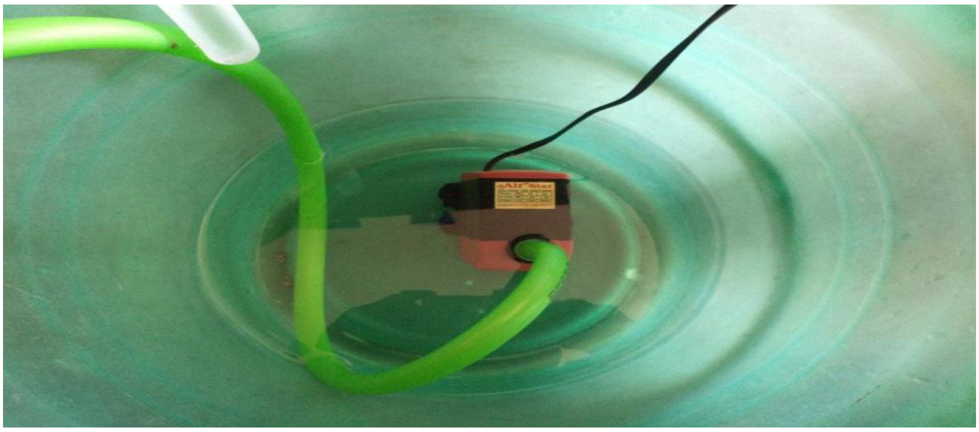


Figure 7.6: Pump

7.2 Measuring Device

Two pressure gauges are used in this set up, one for the measurement of suction pressure before the compressor and other for the measurement of discharge pressure after the compressor.

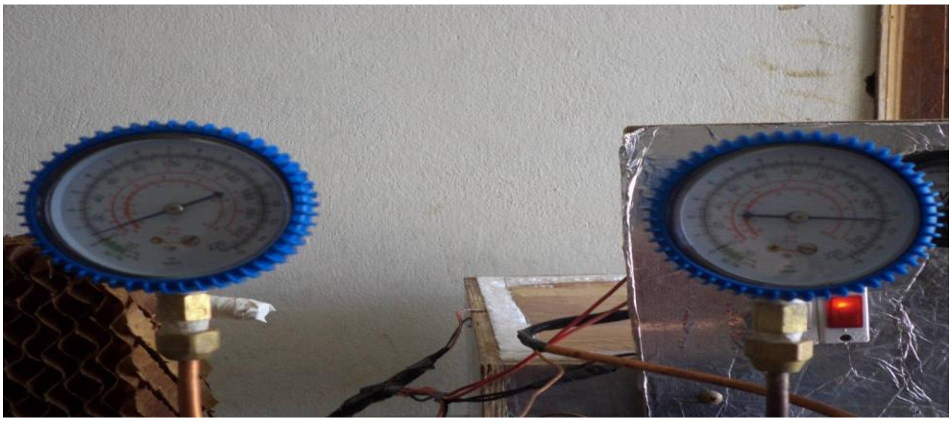


Figure 7.7: Pressure gauge

This is a device used to measure the temperature of the working fluid. The digital thermometer TPM-10 is used, which directly gives the value of temperature at various points in the air system.

Figure 7.8: Digital thermometer

Voltmeter and ammeter are the devices used to measure the voltage and current of the input power to the air conditioning system. Both voltage and ammeter are of dial gauge manual type.

8. EXPERIMENT RESULT AND DISCUSSION

In order to check the performance of vapour compression system which have an evaporative cooled condenser, experimental test are performed in two consequent stages. In first stage, cellulose pad of 7cm and 15cm is used at an ambient temperature 31°C.After getting the result, 7cm and 15cm of cellulose pad is again used at an ambient temperature 33°C.When experiment was being carried out, two parameters were kept in mind. The properties of refrigerant (R134a) and air remained constant (after 20min) throughout the process in order to maintain the steady state condition and data are recorded.

Parameter	**Symbol**	**Unit**	**Ambient air temperature 31°C**		**Ambient air temperature 33°C**	
			Cellulose pad Thickness		**Cellulose pad thickness**	
			7cm	**15cm**	**7cm**	**15cm**
Evaporator Absolute pressure	P_{eva}	Bar	0.5	0.44	0.35	0.65
Condenser Absolute pressure	p_{con}	Bar	10.8	11.17	10.7	10.5
Evaporator exit temperature	T_1	°C	-12.9	-13.1	-13	-13.5

Compressor exit temperature	T_2	°C	44.5	45	45	51.1
Condenser exit temperature	T_3	°C	33.5	34.3	32.4	32.5
Total electric current	I	Ampere	1.5	0.7	1.25	0.72
Total electric voltage	V	Volts	200	210	200	210

Table 8.1: Result obtained by varying pad thickness

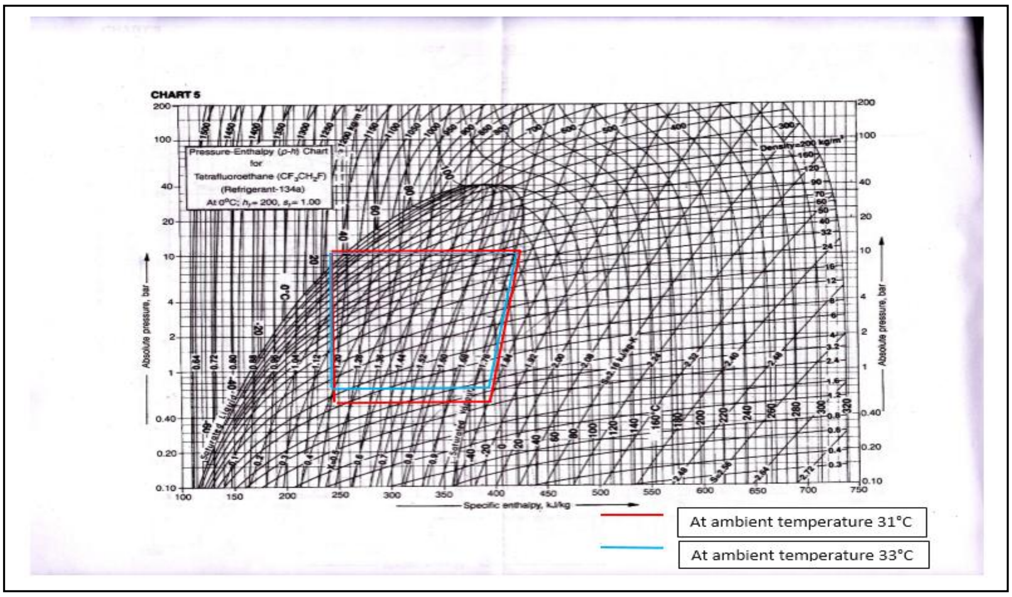


Figure 8.1: Pressure-Enthalpy diagram for evaporative cooled condenser have a thickness of cellulose pad 7cm at an ambient temperature 31°C and 33°C.

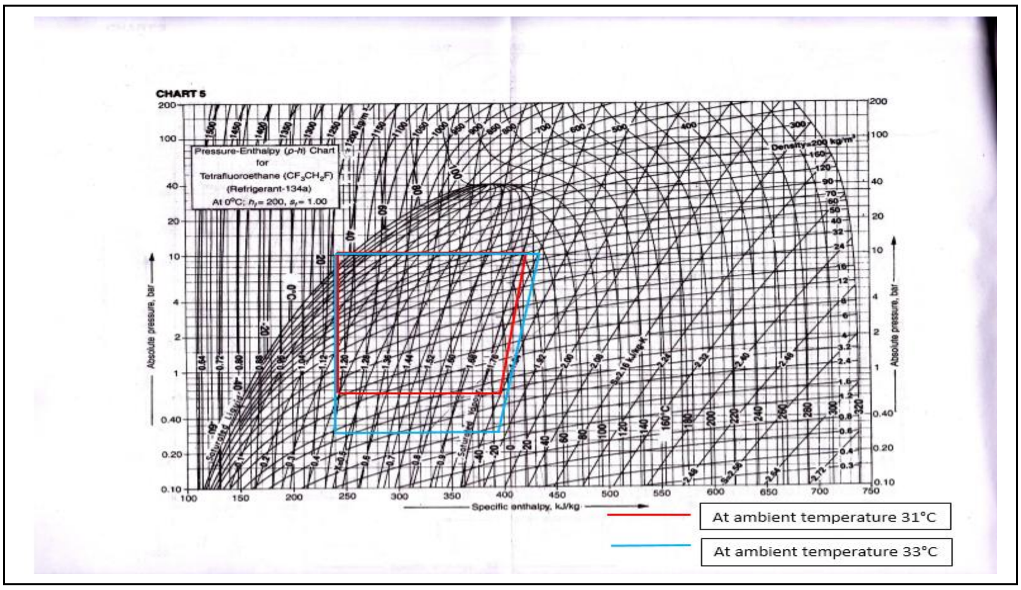


Figure 8.2: Pressure-Enthalpy diagram for evaporative cooled condenser have a thickness of cellulose pad 15cm at an ambient temperature 31°C and 33°C.

9. CALCULATION AND RESULT

While performing the experiment, the result obtained. Based on this result thermodynamic properties of refrigerant R134a are obtained at the different point of the system. In order to calculate the enthalpy, using the P-h chart of the refrigerant R134a and we are getting different parameter by varying the thickness of cellulose of evaporative pad from 7cm to 15cm .Such parameter are compressor work, COP of the system are calculate from the required following equation.

a. Compressor Work $Wc = V * I = m_{ref} * (h_2 - h_1)$

b. Mass flow rate of refrigerant $m_{ref} = \frac{Wc}{(h2 - h1)}$

c. Cooling effect produced $Qr = m_{ref} * (h_1 - h_4)$

d. $COP = \frac{Qr}{Wc}$

Where,

h_1 = enthalpy of refrigerant at inlet of compressor in kj/kg (1)

h_2 = enthalpy of refrigerant at exit of compressor in kj/kg (2)

h_3 = enthalpy of refrigerant at exit of the condenser kj/kg (3)

h_4 = enthalpy of refrigerant at entry of evaporator in kj/kg (4)

The compressor work done is obtained by the input power given to the experimental setup. The voltage and current of the input power is obtained by using the voltmeter and ammeter that attached to the setup.

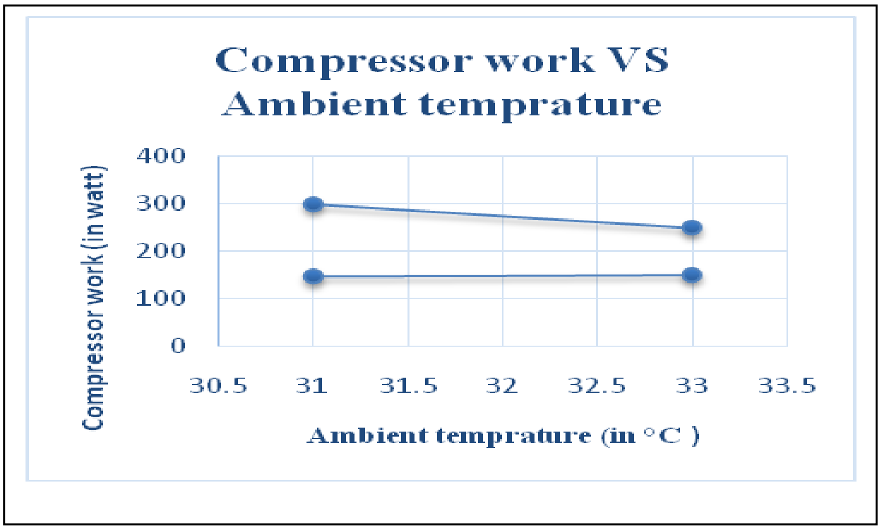
Table 9.1 and 9.2 given the result from the observation table at an ambient temperature 31°C and 33°C by varying the thickness of cellulose pad 7cm to 15cm.

Performance result of Air Conditioner (T_{amb}-31°C)			
Parameter	**Unit**	**7cm Thickness Pad**	**15cm Thickness Pad**
Compressor work W_c	Watt	300	147
COP	------------	4.3939	4.4545

Table 9.1: Result of the experiment at ambient air temperature 31°C

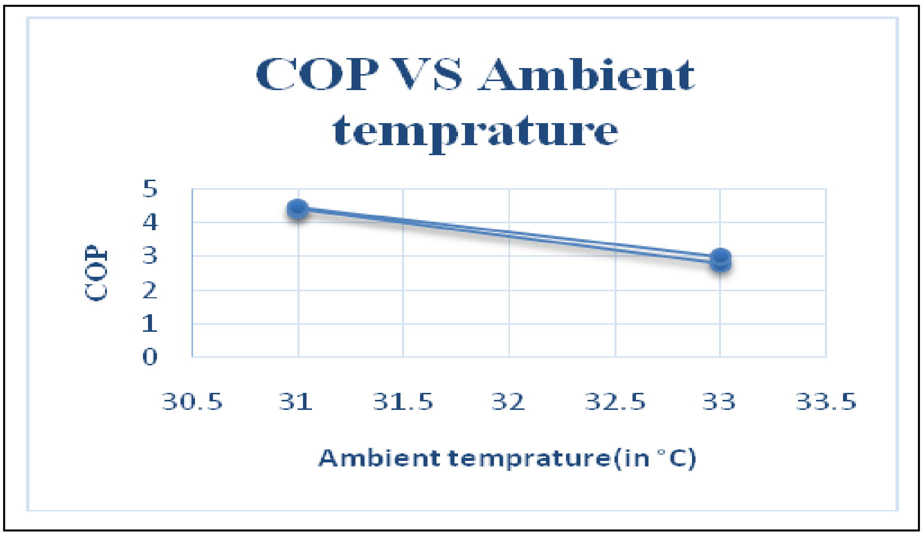
Performance result of Air Conditioner (T_{amb}-33°C)			
Parameter	**Unit**	**7cm Thickness Pad**	**15cm Thickness Pad**
Compressor work W_c	Watt	250	151.2
COP	------------	2.79	2.996

Table 9.2: Result of the experiment at ambient temperature 33°C



Graph 9.1: Compressor work variation with ambient temperature

Effect of ambient temperature on compressor work graph 1 shows that variation of compressor work with ambient temperature which has a two thickness of cellulose pad. The compressor work at 7cm cellulose pad is more than that of 15cm cellulose pad at ambient temperature 31°C.Similarly in second case compressor work is more in 7cm thickness of cellulose pad as compare to 15cm thickness pad for ambient temperature 33°C



Graph 9.2: COP variation with ambient temperature

Effect of ambient temperature on COP graph 2 show that the variation of COP with ambient temperature. The COP at 15cm thickness pad more than that of 7cm thickness pad at ambient temperature31°C.Similarly COP is more in case of 15cm thickness pad as compare to the 7cm thickness pad at same ambient temperature 33°C. Also from the graph COP is more at an ambient temperature 31°C to that of 33°C.

10. CONCLUSION

An evaporative cooled condenser is experimentally investigated. Experimentally result shows that there is considerable change in compressor work when we vary the thickness of cellulose pad at same ambient temperature. But when we compare compressor pressure work at two different ambient temperatures 31°C and 33°C for a same thickness of cellulose pad, compressor work is more in case of 33°C.

Also experimental result shows that there is increase in COP, when we increase the thickness of cellulose pad at the same ambient temperature. But when we compare COP at two different temperature 31°C and 33°C, COP is more at 31°C for both thickness of cellulose pad 7cm and 15cm.There is increase in the COP 0.06 from 7cm to 15cm thickness pad at same ambient temperature 31°C and at the ambient temperature 33°C there is increase in COP 0.2 from 7cm to 15cm.It is also seen that COP decrease 1.6 from ambient temperature 31°C to 33°C when we using 7cm thickness pad. Similarly, COP decrease 1.45 from ambient temperature 31°C to 33°C by using 15cm thickness cellulose pad. Thus increase in thickness of cellulose pad increase the COP of the system at same ambient temperature.

REFERENCES

1. S.D.White, D.J.Cleland, S.D.Cotter, R.A.Stephenson, R.D.S.Kallu, A.K.Fleming, *A heat pump for simultaneous refrigeration and water heating, IPENZ Transaction, Vol.24, No.1, 1997, pp.36-43*.
2. F. W. Yu , K. T. Chan, *Application of Direct Evaporative Coolers for Improving the Energy Efficiency of Air-Cooled Chillers , Journal of Solar Energy Engineering vol. 127 Aug 2005.*
3. Sethi, V.P.Sharma, *S.K. Survey of cooling technologies for worldwide agricultural greenhouse applications. Sol. Energy 2007, 81, 1447–1459.*
4. J.M. Wu, X. Huang and H. Zhang.*Theoretical analysis on heat and mass transfer in a direct evaporative cooler. Appl. Therm. Eng.2009; 29: 980–984.*
5. S. S. Kachhwaha and Suhas Prabhakar, *Heat and mass transfer in direct evaporative cooler. J. Sci. Ind. Res.2010; 69: 705-710.*
6. E. Hajidavalloo, H. Eghtedari, *Performance improvement of air-cooled refrigeration system by using evaporatively cooled air condenser, International Journal of Refrigeration vol. 33 (2010) 982–988*.
7. Dagtekin M. et al. (2011) *the effects of air velocity on the performance of pad evaporative cooling systems, African Journal of Agricultural Research, 6, pp. 1813-1822.*
8. Franco, A., Melikyan, Z. (2011) A *simplified model for analysis of heat and mass transfer in a direct evaporative cooler. Applied Thermal Engineering, 31, pp. 932- 936.*
9. Kulkarni R.K., Rajput S.P.S,(2011) ,*Theoretical Performance Analysis of Indirect-Direct Evaporative Cooler in Hot and Dry Climates, International Journal of Engineering Science and Technology, 3, pp.1239-1251.*

10. Xiangsheng Wu, Xiaofeng Yang, *Performance enhancement of air-cooled chillers with water mist, Experimental and analytical investigation, Applied Thermal Engineering vol. 40 (2012) 114-120.*
11. Adarsh Mohan Dixit,Aditya Desai,Akshay Vyas, *Improving efficiency of air conditioner by cellulose pad,International journal of engineering science & humanities ,ISSN 2250-3552, Volume 3 Issue 1,2013.*
12. V. V. Birangane, A. M. Patil,(2014) *Comparison of Air Cooled and Evaporatively Cooled Refrigerartion Systems – A Review Paper*. *Int. Journal of Engineering Research and Applications. ISSN : 2248-9622, Vol. 4, Issue 6(Version 2), June 2014, pp.208-211.*
13. Rakesh Kumar, Taliv Hussian, Gulshan Sachdeva, *Performance improvement of an small capacity air conditioning system using water cooled and evaporative cooled condenser:Experimental investigation- Proceedings of the 22nd National and 11th International ISHMT/ASME Heat and Mass Transfer Conference December 28-31, 2013, IIT Kharagpur, India.*
14. ASHRAE. *Evaporative Air-cooling Equipment. Chapter 4: Equipment Handbook. Atlanta, GA 30329, USA: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1989.*
15. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Methods of testing for seasonal efficiency of unitary air-conditioners and heat pumps (ASHRAE Standard ANSI/ASHRAE 116-1995), ASHRAE.