ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 8, August 2017

Performance Improvement on Air Conditioning System By Solar Energy Assisted Evaporatively Cooled Air Condenser

[1] Bhargav K, [2] Ajith Kumar S, [3] Arunan Balajee K A

Abstract— **Reduction of energy consumption is a major concern in vapour compression cooling systems, especially in areas with very hot weather conditions. In the hot weather conditions performance of these systems decrease sharply and electrical power consumption increases considerably. Evaporative condensers enhance the heat rejection process by using the cooling effect of evaporation and therefore improve energy usage efficiency. Increasing the co-efficient of performance (COP) of the residential air conditioner with air-cooled condenser is a challenging problem especially in areas with very hot conditions. Applications of solar energy assisted evaporatively cooled air condenser instead of air cooled condenser is proposed in this project work as an efficient way to solve the problem. Experimental results show that the inlet air temperature for evaporatively cooled condenser has been reduced by 3.02% compared to air cooled condenser. Also the time taken for the compressor to cut off has been reduced for evaporatively cooled condenser by 69.5 % (flow rate 8.5L/min; temperature range=22-20 °C) compared to conventional air conditioner.**

Index Terms— **Air conditioner, Cellulose Pad, Water pump, Pressure gauges, Temperature sensors**.

INTRODUCTION

Since prehistoric times, snow and ice were used for cooling. The business of harvesting ice during winter and storing for use in summer became popular towards the late 17th century. This practice was replaced by mechanical ice-making machines.

The basic concept behind air conditioning is said to have been applied in ancient Egypt, where reeds were hung in windows and were moistened with trickling water. The evaporation of water cooled the air blowing through the window. This process also made the air more humid, which can be beneficial in a dry desert climate. In Ancient Rome, water from aqueducts was circulated through the walls of certain houses to cool them.

Air conditioning is the process of removing heat from a confined space, thus cooling the air, and removing humidity. Air conditioning can be used in both domestic and commercial environments. This process is used to achieve a more comfortable interior environment, typically for humans or animals; however, air conditioning is also used to cool/dehumidify rooms filled with heat-producing electronic devices, such as computer servers, power amplifiers, and even to display and store artwork.

When a liquid converts to a gas (in a process called phase conversion), it absorbs heat. Air conditioners exploit this feature of phase conversion by forcing special chemical compounds to evaporate and condense over and over again in a closed system of coils. The compounds involved are refrigerants that have properties enabling them to change at relatively low temperatures. Air conditioners also contain fans that move warm interior air over these cold, refrigerant- filled coils.

When hot air flows over the cold, low-pressure evaporator coils, the refrigerant inside absorbs heat as it changes from a liquid to a gaseous state. To keep cooling efficiently, the air conditioner has to convert the refrigerant gas back to a liquid again. To do that, a compressor puts the gas under high pressure, a process that creates unwanted heat. All the extra heat created by compressing the gas is then evacuated to the outdoors with the help of a second set of coils called condenser coils, and a second fan. As the gas cools, it changes back to a liquid, and the process starts all over again. The cold side of an air conditioner contains the evaporator and a fan that blows air over the chilled coils and into the room. The hot side contains the compressor, condenser and another fan to vent hot air coming off the compressed refrigerant to the outdoors. In between the two sets of coils, there's an expansion valve. It regulates the amount of compressed liquid refrigerant moving into the evaporator. Once in the evaporator, the refrigerant experiences a pressure drop, expands and changes back into a gas. The compressor is actually a large electric pump that pressurizes the refrigerant gas as part of the process of turning it back into a liquid. There are some additional sensors, timers and valves, but the evaporator, compressor, condenser and expansion valve are the main components of an air conditioner.

Air conditioners monitor and regulate the air temperature via a thermostat. They also have an onboard filter that removes airborne particulates from the circulating air. Air conditioners function as dehumidifiers. Because temperature is a key component of relative humidity, reducing the temperature of a volume of humid air causes it to release a portion of its moisture.

Air conditioners often use a fan to distribute the conditioned air to an occupied space such as a building or a car to improve thermal comfort and indoor air quality. Electric refrigerant-based AC units range from small units that can cool a small bedroom, which can be carried by a single adult, to massive units installed on the roof of office towers that can cool an entire building. The cooling is typically achieved through a refrigeration cycle, but sometimes evaporation or free cooling is used.

In the refrigeration cycle, heat is transported from a colder location to a hotter area. As heat would naturally flow in the opposite direction, work is required to achieve this. A refrigerator is an example of such a system, as it transports the heat out of the interior and into its environment. The refrigerant is used as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere.

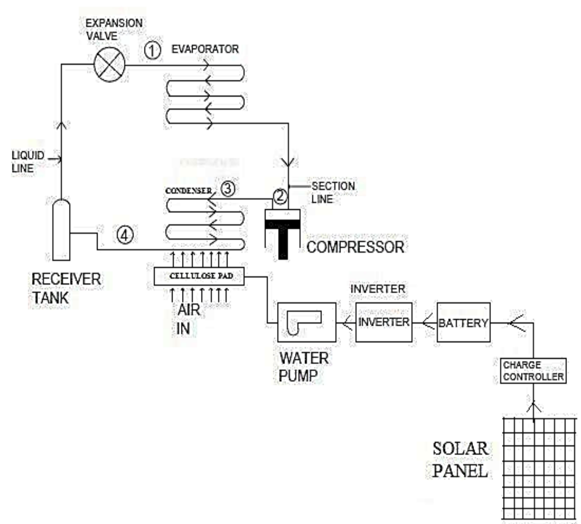
Circulating refrigerant vapour enters the compressor, where its pressure and temperature are increased. The hot, compressed refrigerant vapour is now at a temperature and pressure at which it can be condensed and is routed through a condenser. Here it is cooled by air flowing across the condenser coils and condensed into a liquid. Thus, the circulating refrigerant removes heat from the system and the heat is carried away by the air. The removal of this heat can be greatly augmented by pouring water over the condenser coils, making it much cooler when it hits the expansion valve.

The condensed, pressurized hot liquid refrigerant is next routed through an expansion valve where it undergoes an abrupt reduction in pressure. That pressure reduction results in flash evaporation of a part of the liquid refrigerant, greatly lowering its temperature. The cold refrigerant is then routed through the evaporator. A fan blows the interior warm air (which is to be cooled) across the evaporator, causing the liquid part of the cold refrigerant mixture to evaporate as well, further lowering the temperature. The warm air is therefore cooled and is pumped by an exhaust fan/ blower into the room.

To complete the refrigeration cycle, the refrigerant vapour is routed back into the compressor. In order for the process to have any efficiency, the cooling/evaporative portion of the system must be separated by some kind of physical barrier from the heating/condensing portion, and each portion must have its own fan to circulate air.

BTU and EER

Most air conditioners have their capacity rated in British thermal units (Btu). A Btu is the amount of heat necessary to raise the temperature of 1 pound (0.45 kilograms) of water one degree Fahrenheit (0.56 degrees Celsius). One Btu equals 1,055 joules. In heating and cooling terms, one ton equals 12,000 Btu



SPECIFICATIONS

An existing split-air-conditioner (1.5ton) made by Samsung was used in the experiments. In the shape of the condenser, a frame was built and filled by cellulose media pad (corrugated packing) with thickness of 5cm and installed in front of the Outdoor unit as shown in Fig3.13. A water circulation system, including a small pump (220v, 20W), a Collecting tank, and connecting pipes were assembled on the system to inject water on the top of the Cellulose pad. The water circulation rate was different for each test. The Various flow rates were (6,7,8.5 L/min). The Pump is operated using Solar panel, the solar panel, which collects solar energy and it gets converted into electrical energy and gets stored into battery using charge controller. An inverter circuit is used to convert Direct Current (D.C) into Alternating Current (A.C) to run the pump

II. EXPERIMENTAL WORKING OF AC AND EC

Gas, a refrigerant, is fed into the compressor where it is pressurized. This also causes the heat in the gas to rise. The pressurized gas then goes through a succession of tubes that are meant to condense it into a liquid. The liquid is still pressurized and travels through the condenser tubes until they come to an expansion joint. The pressurized liquid passes through this point in the process and becomes a gas again as the pressure is rapidly reduced. During the reduction of pressure the gas also releases a great deal of heat and becomes much cooler (thus, refrigerant). The gas then passes back to the compressor to repeat that process. Air from the room is drawn into the unit and passes over the evaporator coils. This action cools the air significantly which is then forced back into the room via the blower. The air continues to circulate through the air conditioner until a set temperature (set by the thermostat) is reached. At this point the apparatus shuts off automatically. In conventional air conditioning system, the refrigerant changes it's phase in evaporator due to absorption of room temperature and it is passed into compressor, condenser, expansion valve and the cycle goes on. In order to decrease the temperature of the air entering the condenser unit, we are introducing a cellulose pad placed before the outdoor unit. The water is fed into the cellulose pad using a pump powered by monochromatic Photovoltaic solar collectors. The air from atmosphere gets pre- cooled as it passes through the cellulose pad. Thus the cycle continues as the pre-cooled air passes through the condenser and required cooling is obtained with a reduced load and change of phase occurs rapidly. This ultimately reduces the power consumption of the air conditioner and increases the COP.

III. PERFORMANCE CALCULATIONS

A. Equations

W = V ∗ I

h1= hf1+x1*hfg1=387.5kJ/kg

h2=hg2 @ 76.2=415.22 kJ/kg h3=h4= hf3@33.1=240.5 kJ/kg ṁ= W/(h2-h1)

Qr= ṁ*(h1-h3) COP=Qr/W

B. Model COP calculation

Conventional method

W = V ∗ I

W =7.8*220=1.716kW

T1=15.5 °C; T2=76.2 °C; T3=33.1°C; T4= 6.5 °C;

h1= hf1+x1*hfg1=387.5kJ/kg h2=hg2 @ 76.2=415.22 kJ/kg h3=h4= hf3@33.1=240.5 kJ/kg

ṁ= W/(h2-h1)

ṁ= 1.716*(0.4)/(415.22-387.5)=0.0247kg/s

Qr= ṁ*(h1-h3)

Qr=0.0247*(387.5-240.5)=3.64kW

COP=Qr/W COP=3.64/(1.716*0.4)=4.92

COP=4.92

Evaporatively Cooled Condenser

For Flow rate=8.5lit/min W=V*I W=6.8*220=1.496kW

T1=14.5 ° C; T2=70.2 ° C; T3= 32.1 ° C; T4 =5.4 ° C;

h1= hf1+x1*hfg1 =391.1kJ/kg h2=hg2 @70.2 = 415.21 kJ/kg h3=h4= hf3@32.1=239.25kJ/kg

ṁ= W/(h2-h1)

ṁ=1.496*(0.4)/(415.21-391.1)=0.0248kg/s

Qr= ṁ*(h1-h3)
Qr=0.0248*(391.1-239.25)=3.768kW

COP=Qr/W COP=3.768/(1.496*0.4)=6.298

COP=6.298

%variation in C.O.P = {Increase in COP-Actual COP/(Actual COP)}*100

%Variation in COP=28%

IV. EXPERIMENTAL RESULTS

In order to estimate the effect of evaporative cooler on the System and compare the results of two different types of air Conditioners, experimental tests were performed in two Consequent stages. In the first stage, air-cooled condensers were used and after getting the data, in the second stage evaporatively cooled condenser were used. Data were recorded after steady state condition was established in the system and the properties of refrigerant and air remained constant (after 20 min). Many experimental tests were performed at different ambient temperatures (33° C, 35° C,

38° C) , different room temperature interval(20-22° C, 22-24° C, 24-26° C, 26-28° C) and different flow rate(8.5 l/min, 6 l/min, 5l/min).

In conventional air conditioning system, the refrigerant changes its phase in evaporator due to absorption of room temperature and it is passed into the compressor, condenser, expansion valve and the cycle go on. In order to decrease the temperature of the air entering the condenser unit, the cellulose pad setup, placed before the Outdoor unit, cools the air from the atmosphere and it passes into the condenser. The condenser cools the refrigerant and changes its phase faster than the conventional process. And, the cycle continues and the required cooling is obtained with the reduced load which ultimately reduces the power consumption of the air conditioner and increases the COP.

The testing process begins for conventional air conditioner with the ambient temperature of 33°C, Room temperature of 28°C and the cut off temperature was set to 26°C, Once the compressor has been cut off, various parameters such as compressor exit temperature, condenser exit temperature, evaporator in temperature, evaporator exit temperature, back pressure, delivery pressure and cut-off time were noted. With the known temperatures and pressure at various points aids in calculating the enthalpy at respective points, with the known values of enthalpy, refrigeration effect and COP were calculated. And using a digital clamp meter, Current required to run the compressor was noted and with that work done by the compressor was calculated the above process were repeated for different temperature intervals(26-24°C,24-22°C&22-20°C). For evaporatively cooled condenser, various parameters such as compressor exit temperature, condenser exit temperature, evaporator in temperature, evaporator exit temperature, back pressure, delivery pressure and cutoff time were noted down and Refrigeration effect, work done by the compressor and COP were calculated using similar method. In evaporatively cooled condenser, various flow rates were changed in order to study the effect of water circulation rate in COP. Above mentioned process were repeated at different ambient conditions (35°C & 38°C). The graph was plotted for different flow rates at each ambient condition between Temperature intervals and refrigeration effect, work done by the compressor and COP. Variations in COP between Conventional air condenser and evaporatively cooled air condenser were calculated and graph was plotted. Window-air-conditioners are rapidly being replaced by split type air conditioners due to their better performance and

S.No	Parameters	conventional	Flow rate8.5l/m	Flow rate 7 l/m	Flow rate6 l/m
1.	Compressor Temperature °C	76.2	70.2	70.9	72.7
2.	Evaporator In Temperature °C	6.5	5.4	5.9	6.3
3.	Evaporator Out Temperature °C	15.5	14.5	14.8	15.3
4.	Condenser Temperature °C	33.1	32.1	32.5	32.9
5.	Delivery Pressure (psi)	280	280	280	280

IFERP
connecting engineers... developing research
ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 8, August 2017

6.	Back Pressure (psi)	58	58	58	58
7.	Cut off time (mins)	5.32	4.58	4.8	5
8.	Power consumed by compressor (kW)	1.716	1.496	1.51 8	1.562
9.	Mass flow Rate(kg/s)	0.0247	0.0248	0.02 5	0.024 8
10.	Refrigeration Effect (kW)	3.64	3.76	3.78	3.70
11.	C.O.P	4.92	6.29	6.22	5.92

1 Comparison of various parameters between AC & EC at 28-26°C lower noise. In this work, experimental investigation was used to evaluate the effect of using an evaporatively cooled air condenser on the performance of an air-cooled split-air- conditioner under variable ambient air conditions in order to show how much COP and power consumption could be improved by changing the system.

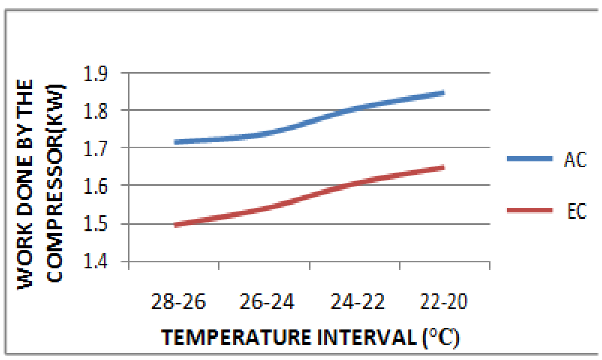


Fig 1 Temperature Interval vs. Work done by compressor

The above figure 1 deals with the comparison of Work done by the compressor between air cooled(AC) condenser and evaporatively cooled condenser for flow rate 8.5 L/min and temp 35 °C . It can be seen that AC has higher Work done than EC. For EC and AC ,Work done by the compressor gradually increases with increase in temp range.

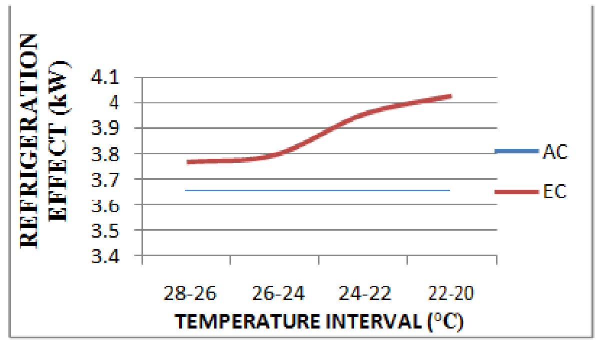
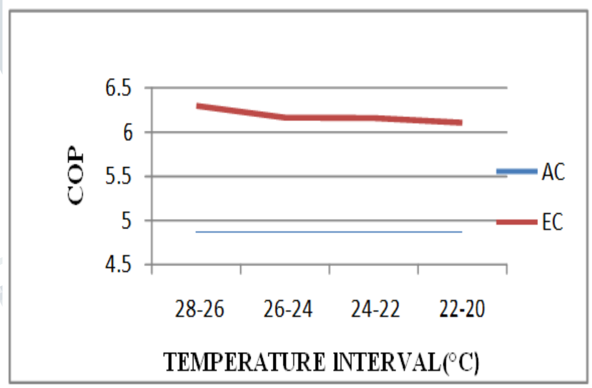


Fig 2 Temperature Interval vs. Refrigeration effect

The above graph 2 deals with the comparison of Refrigeration effect between air cooled(AC) condenser and evaporatively cooled condenser(EC) for flow rate 8.5 L/min and temp 35 °C . It can be seen that AC has lower refrigeration effect than EC, for EC and AC decrease in temperature range increases the refrigeration effect.



The above figure 3 deals with the comparison of COP between air cooled(AC) condenser and evaporatively cooled condenser(EC) for flow rate 8.5 L/min and temp 35 °C . It can be seen that EC has higher COP than AC. for EC and AC decrease in temperature range decreases the COP.

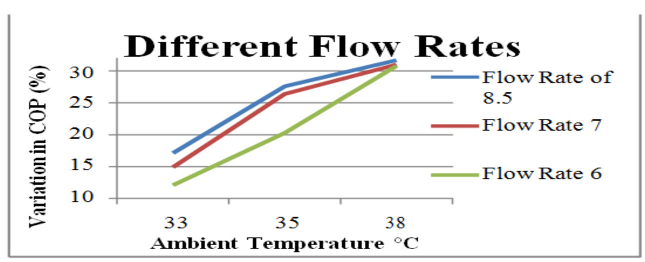


Figure 4 Ambient temperature vs. Variation in COP

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 8, August 2017

The above Figure 4 deals with the comparison of COP of EC in different ambient temperatures at different flow rates. It is observed that the variation in COP values are increasing with increase in ambient temperature. It can be inferred from the figure that the reduction in flow rate, at a local point, can decrease the Co-efficient of Performance of Air conditioner at that point.

NOMENCLATURE

- Air cooled condenser AC
- Evaporative cooled Condenser EC
- T1=Evaporator Out temperature (°C)
- T2=Compressor Out temperature (°C)
- T3=Condenser Out temperature (°C)
- T4=Evaporator In temperature (°C)
- h1=Enthalpy @T1 (kJ/kg)
- h2=Enthalpy @T2 (kJ/kg)
- h3=Enthalpy @T3 (kJ/kg)
- h4=Enthalpy @T4 (kJ/kg)
- W=Work done by the compressor (kW)
- V=Voltage
- A=Current
- ṁ=mass flow rate(kg/s)
- Qr=Refrigeration Effect (kW) C.O.P=Coefficient of performance

V. CONCLUSION

Experiments were conducted with both air cooled and evaporatively cooled condenser to study the COP, Refrigeration effect, work done by the compressor and running time of the compressor. The results are explained briefly.

For Evaporatively air cooled condenser, the Temperature at various points of the air conditioner is reduced compared to air cooled condenser. The inlet air temperature for evaporatively cooled condenser has been reduced by

3.02% compared to air cooled condenser. The time taken for the compressor to cut off has been reduced for evaporatively cooled condenser by 69.5 % (flow rate 8.5L/min; temperature range=22-20°C ambient Temperature 35°C) compared to conventional air conditioner. The refrigeration effect has been improved by 3.5% for evaporatively cooled condenser than conventional air conditioners. The work done by the compressor has been reduced for evaporatively cooled condenser by 12.8% than air cooled condenser. The co-efficient of performance of the evaporatively cooled condensed air conditioner has been improved by 28% compared to air cooled condensed air conditioner. The total power consumed by the Evaporatively cooled condensed air conditioner was reduced by 32.5 %(flow rate 8.5L/min; temperature range=24-22°C; ambient Temperature 35°C) than conventional air conditioners From the above results, it has been concluded that the performance of the air conditioner is improved by using solar assisted evaporatively cooled condenser.

REFERENCES

[1] A.K. Pandey et al [4]. Recent advances in solar photovoltaic systems for emerging trends and advanced applications- Renewable and Sustainable Energy Reviews 53(2016)859–884

[2] E. Hajidavalloo et al [1]. Performance improvement of air-cooled refrigeration system by using evaporatively cooled air condenser- international journal of refrigeration 33(2010)982–988

[3] E. Hajidavalloo. Application of evaporative cooling on the condenser of window-air-conditioner- Applied Thermal Engineering 27 (2007) 1937–1943

[4] E. Mohammed Ahmed et al [3]. Performance evaluation of three different types of local evaporative cooling pads in greenhouses in Sudan- Saudi Journal of Biological Sciences.

[5] J. Xu et al [4]. Experimental performance of evaporative cooling pad systems in greenhouses in humid subtropical climates- Applied Energy 138(2015) 291–301

[6] K. Harby et al [3]. Performance improvement of vapour compression cooling systems using evaporative condenser: An overview- Renewable and Sustainable Energy Reviews 58(2016)347–360

[7] M. Ohnishi et al [3]. Advanced Photovoltaic Technologies and Residential Applications- Renewable Energy, Vol. 6, No. 3, pp. 275-282, 1995

[8] M.R. Islam et al [2]. Experimental and numerical study of an evaporatively-cooled condenser of air- conditioning system- Energy xxx (2015) 1e10

[9] N.I. Ibrahim et al [2]. Experimental investigation of a vapour compression system with air pre-cooling by condensate Applied Thermal Engineering 110 (2017) 1255–1263

[10] O.A. Alawi et al [2]. Applications of nano refrigerant and nano lubricants in refrigeration, air- conditioning and heat pump systems:A review- International Communications in Heat and Mass Transfer 68 (2015) 91–97

[11] P. Martinez et al [4]. Experimental study on energy performance of a split air-conditioner by using variable thickness evaporative cooling pads coupled to the condenser- Applied thermal Engineering

[12] R. Saidur et al [4]. A review on the performance of nanoparticles suspended with refrigerants and lubricating oils in refrigeration systems- Renewable and Sustainable Energy Reviews 15 (2011) 310–323

[13] R. Wang et al [2]. Use of nanoparticles to make mineral oil lubricants feasible for use in a residential air conditioner employing hydro-fluorocarbon refrigerants- Energy and Buildings 42 (2010) 2111– 2117

[14] S.S. Hu et al [1]. Study of a high efficiency residential split water-cooled air conditioner- Applied Thermal Engineering 25 (2005) 1599–1613

[15] T. Wang et al [2]. Experimental investigation of air conditioning system using evaporative cooling condenser- Energy and Buildings T.F. Hou et al [4]. Cellulose pad water cooling system with cold storage- international journal of refrigeration 69(2016)383–393

[16] V. Jain et al [2].A financial feasibility evaluation of using evaporative cooling with air-conditioning (hybrid mode) in commercial buildings in India- Energy for Sustainable Development 17 (2013) 47– 53

[17] W.L. Lee et al [2]. Modelling the performance characteristics of water-cooled air conditioners- Energy and Buildings 40 (2008) 1456–1465

[18] X. Hao et al [5]. Optimizing the pad thickness of evaporative air-cooled chiller for maximum energy saving- Energy and Buildings 61(2013)146–152

[19] Y. Li et al [4]. Performance study of solar photovoltaic air conditioner in the hot summer and cold winter zone- Solar Energy 117 (2015) 167–179