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Performance measurement of Window Air conditioning system by introducing Sub-cooling effect by water spray

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Abstract-*In recent era, energy crisis is the main obstacle for the growth of the nation. To meet the requirement of electricity, there are two ways either generation of more electricity or saving electricity. Here, saving in electrical energy option has been adopted for the window Air-conditioner which can be possible by increasing the C.O.P. by introducing sub-cooling effect on condenser. The sub-cooling effect will be produced by using water sprinkled (natural) condenser and performance will be measured in terms of C.O.P., refrigerating effect and power consumption. The comparative study of air cooled condenser Air conditioning system and water cooled condenser Air conditioning system has been carried out.*

Key words: Energy crisis, Water cooled condenser, Sub-cooling, Sprinkle system, Air-conditioning.

1. INTRODUCTION

Window air-conditioner is a common household appliance which consists of two units, inside unit and outside unit as shown in figure-1. Inside unit consists of heat exchanger/evaporator which absorbs heat from the confined place to be cool and a blower which blows cool air and maintains the air flow or motion in the place to be cooled. Outside unit consists of compressor, heat exchanger/condenser and a fan. Basically, window air conditioning system consists of four basic components: Compressor, Condenser, Expansion device (Capillary) and Evaporator. Window air conditioner works on vapour compression refrigeration (VCR) cycle as shown in figure-2. From this figure, COP of Air-conditioning system can be found out.

C.O.P= Desired effect / input or work done

C.O.P= Heat removed/ work done (compressor work)

= (h1-h4) / (h2-h1)

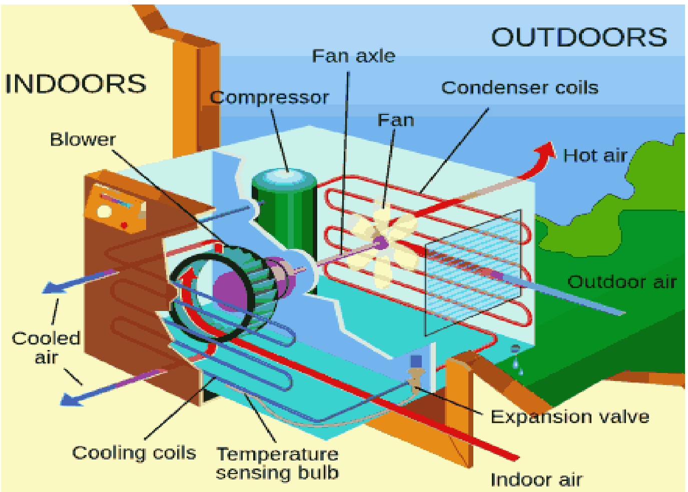

Fig.1: Window Air conditioner

(PC: https://upload.wikimedia.org/wikipedia/commons/thumb/f/f2/Air_conditioning_unit-en.svg/1157px-Air_conditioning_unit-en.svg.png)

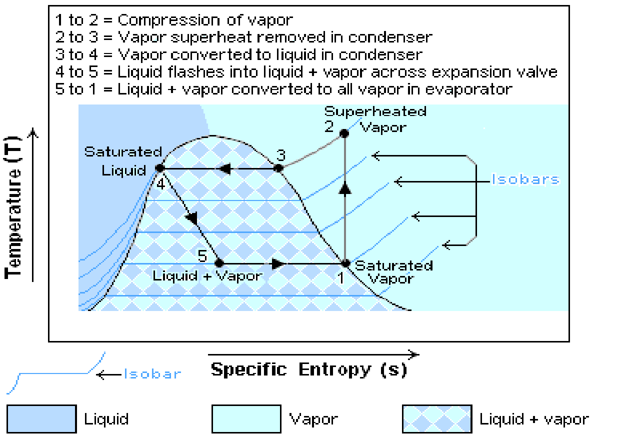

Fig.2: T-S diagram of Vapour compression cycle

(PC: https://upload.wikipedia.org/wikipedia/commons/f/f7/RefrigerationTS.png)

As shown in the figure- 2, at point-1 the circulating refrigerant enters the compressor, in as a saturated vapour, which compresses the refrigerant to state point-2. From point-2 to 3, the superheated refrigerant vapour travels through the part of the condenser in which heat from refrigerant is rejected in surrounding. Between point-3 and 4, the refrigerant vapour travels through the remainder part of the condenser and is condensed into a saturated liquid. The condensation process ideally occurs at constant pressure.

Between point – 4 and 5, the saturated liquid refrigerant passes through the expansion device and undergoes an abrupt decrease of pressure. That process results in the adiabatic flash evaporation and auto-refrigeration of a portion of the liquid. The adiabatic flash evaporation process is isenthalpic (h=constant).

Between point - 5 and 1, the cold and partially vapourised refrigerant travels through the the evaporator in which refrigerant is vapourised by warm air (from the space to be cooled). The evaporator process ideally occurs at constant pressure. The resulting saturated refrigerant vapour returns to the compressor inlet at point-1 and the thermodynamic cycle repeats.

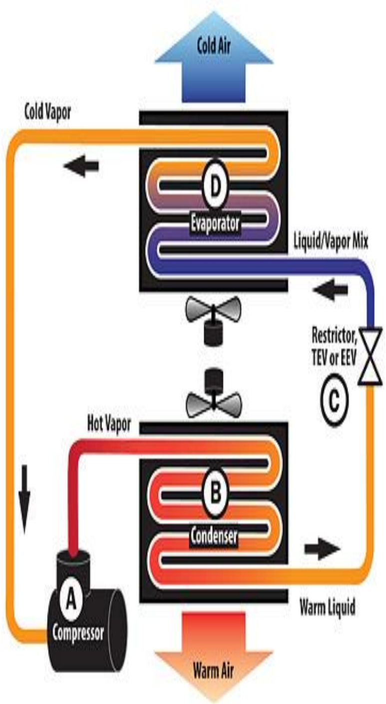

Fig.3: Simple VCRS cycle

(PC:http://www.achrnews.com/ext/resources/2011/09-05-11/Slideshow-W-1-1-Frost---Defrost-figure-1-flipped1.jpg)

2. SUB-COOLING EFFECT

Normally in vapour refrigeration process, the refrigerant is used in the cycle and its phase is changed due to the latent heat transfers in condenser and in evaporator. In evaporator refrigerant is absorbed heat from the space which is to be cooled. Sub-cooling refers to the cooling of liquid refrigerant leaving the condenser. Sub-cooling is an important process in VCR system which affects the performance of VCR system. A small degree of sub-cooling of liquid refrigerant after the condenser is used to reduce the mass of vapour format during expansion, so that the vapour bubbles do not impede the flow of liquid refrigerant through the expansion valve. If the temperature of refrigerant, leaving from the condenser coil, is decreased by means of some external heat exchanger device which leads to additional cooling effect in evaporator without changing the compressor work which leads to the improvement in performance of VCR system.

3. THEORY OF ANALYSIS

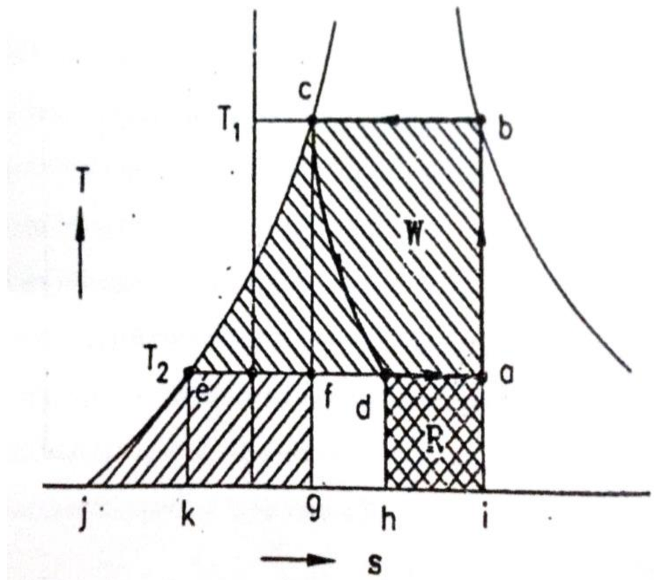

Fig.4: T-S Diagram of VCR cycle

Here assumption is made that refrigerant is dry and saturated at the end of compression, for that work done and refrigeration effect is calculated as below.

Work done (W) = area ‘abcea’ = area ‘bcjib’ – area ‘aejia’

Refrigeration effect (R) = heat at ‘a’ – heat at ‘d’

= area ‘aejia’ – area ‘dejhd’

= area ‘adhia’

C.O.P = R/W = area ‘adhia’ /area ‘abcea’

4. EXPERIMENTAL SETUP

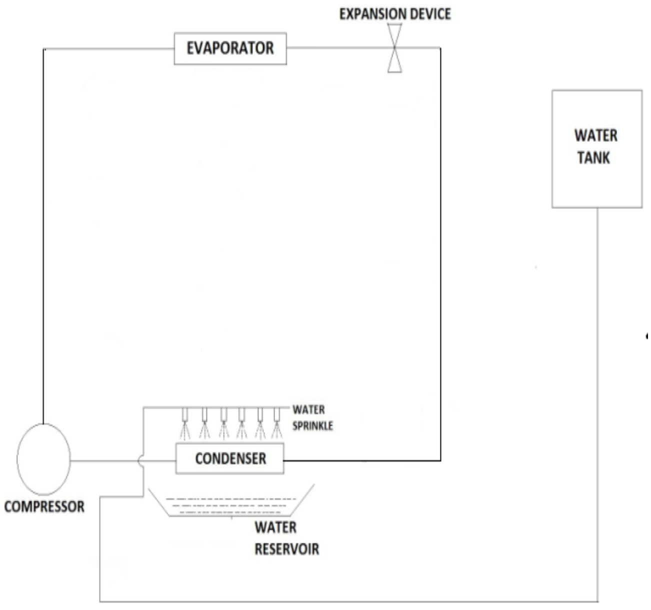

Fig.5: Layout of experimental setup

Fig.6: Experimental set-up

5. COMPONENT SPECIFICATION

Fig.7: 3-Dimensional view of sprinklers containing pipe

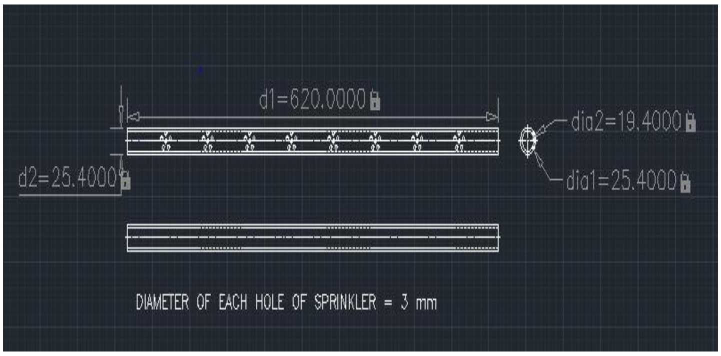

Fig.8: 2-Dimensional view of sprinklers containing pipe

A. Refrigeration capacity of window air conditioning system: 1.5 TR

B. Compressor: Reciprocating type, Hermitically sealed, 1/4 HP, 230 V, 50 Hz, A.C. only 1.1 Amp. Max.

C. Refrigerant: R22 ($CHClF_2$)

D. Copper plate: 300 mm*300 mm*1 mm

E. Pipe Dimensions:

- Diameter = 25.4 mm
- Length = 620 mm
- Thickness = 3 mm

F. Sprinkler’s Dimensions:

- No. of Sprinklers = 8
- No. of holes in each sprinkler = 6
- Sprinkler diameter = 15 mm
- Hole diameter = 3 mm
- Center distance between two successive sprinklers = 70 mm

G. Height of water tank = 5 m

H. Volume of wooden Casing = 0.10881 m^3

6. OBSERVATIONS

In the experimentation, observation for the temperatures and pressures at different point of window air conditioning system has been recorded at the interval of five minute. But in this paper, observations are shown for the quasi-steady state situation (after 15 minute) for the (1) With Air cooled condenser air conditioning system (2) With Water cooled condenser air conditioning system

6.1. For Air cooled condenser system

Inlet pressure of Compressor, P_1 = 3.7023 bar

Outlet pressure of Compressor, P_2 = 15.8370 bar

Compressor Inlet = CM.I

Condenser Inlet = CN.I

Capillary Inlet = CP.I

Evaporator Inlet = EV.I

Space to be cooled = SC

Table-1: Observations of Air-cooled condenser system

	CM.I	CN.I	CP.I	EV.I	SC
Time (min)	T_1 (°c)	T_2 (°c)	T_3 (°c)	T_4 (°c)	T_5 (°c)
15	-4	58	38	-8	-5

6.2. For water cooled condenser system

Inlet Pressure of Compressor, P_1 = 3.082 bar

Outlet Pressure of Compressor, P_2 = 12.389 bar

Flow rate of water Q = 0.08453 × 10^{-3} m^3/sec

Table-2: Observation of Water cooled condenser system

	CM.I	CN.I	CP.I	EV.I	SC
Time (min)	T_1 (°c)	T_2 (°c)	T_3 (°c)	T_4 (°c)	T_5 (°c)
15	5	61	27	-12	-6

7. CALCULATIONS

Calculations were carried out for the all observations but in the present paper calculations are shown for one observation for each condition.

7.1. Calculation for Air cooled condenser system

Taking reading of the observation,

h_1 = 247.73 kJ/kg

h_2 = 272.70 kJ/kg

h_3 = 97.73 kJ/kg

Refrigerating Effect

R.E. = $h_1 - h_3$

= 247.73 – 97.73

= 150 kJ/kg

Mass of Refrigerant

M.O.R = (TR*210)/R.E.

= (1.5*210)/150= 2.1 kg/min

Work done

Work done = $h_2 - h_1$

= 272.7 – 247.73

= 24.97 kJ/kg

Co-efficient Of Performance

C.O.P. = Refrigerating Effect/Work done

= 150/24.97

= 6.00

Power Consumption

P.C. = M.O.R(Work done)/60

= 2.1(24.97)/60

= 0.87395 kW

7.2. Calculation for Water cooled condenser

Taking reading of the observation,

h_1 = 255.11 kJ/kg

h_2 = 277.93 kJ/kg

h_3 = 82.688 kJ/kg

Refrigerating Effect

R.E. = $h_1 - h_3$

= 255.11 – 82.688

= 172.42 kJ/kg

Mass of Refrigerant

M.O.R = (TR*210)/R.E.

= (1.5*210)/172.42

= 1.8269 kg/min

Work done

W.D. = $h_2 - h_1$

= 277.93 – 255.81= 22.82 kJ/kg

Co-efficient Of Performance

C.O.P. = Refrigerating effect/Work done

= 172.42/22.82 = 7.55

Power Consumption

P.C. = M.O.R(Work done)/60

= 1.8269(22.82)/60

= 0.6948 kW

8. RESULT

Sr. No.	Parameters	With Air-cooled Condenser	With Water-cooled Condenser
1	Refrigerating Effect (kJ/kg)	150	172.42
2	Work done (kJ/kg)	24.97	22.82
3	Mass of Refrigerant (kg/min)	2.10	1.8269
4	C.O.P. Of Cycle	6.00	7.55
5	Power Consumption (kW)	0.8739	0.6948

9. CONCLUSION

From results it has been found that,

- The performance of Air conditioning system (window Air conditioner) can be improved by using water cooled condenser instead of air cooled condenser. From the observations, it has been found that maximum C.O.P and refrigerating effect of air conditioning system is obtained when water cooled condenser is used.

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