Performance Measurement of Window Air Conditioner by Introducing Thermoelectric Module

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Abstract— In current scenario, energy crisis is the bottleneck 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 (window air conditioning system) which can be possible by increasing the C.O.P. either by sub-cooling or superheating effect. In the present work, performance of window air conditioner has been measured without thermoelectric modules (TEM), by introducing single TEM and Two TEM which. TEM works on Peltier effect, which provides sub-cooling and superheating effect in window air conditioning system. The comparative study of obtained results was carried out for the window air conditioning system without TEM, with single TEM and with double TEM.

Key words: Energy crisis, Thermoelectric Module, Air conditioning

I. 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.

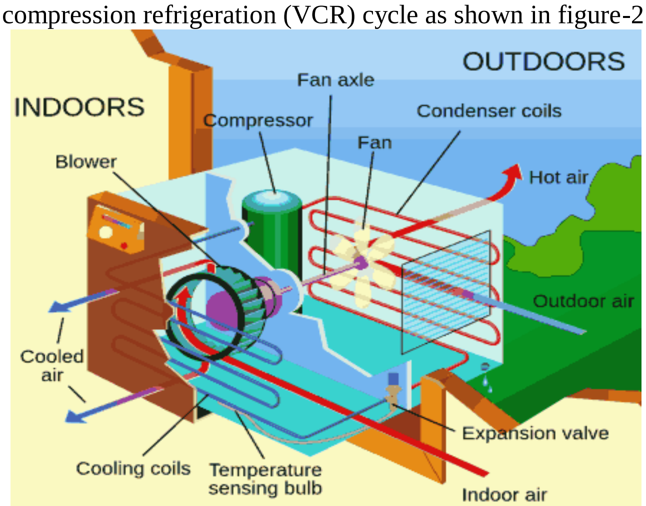

Fig.1: Window Air conditioning system

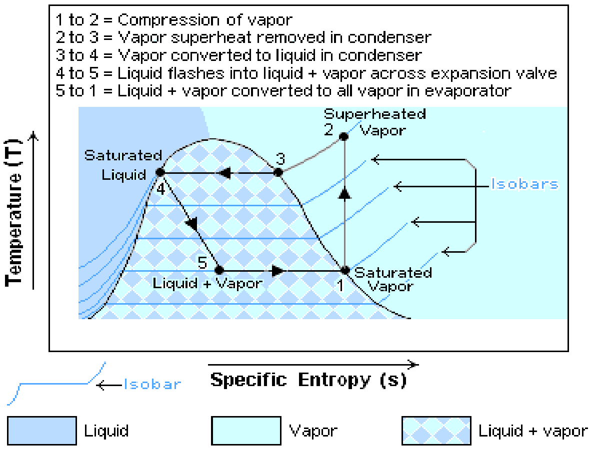

Fig. 2: T-S diagram of Vapour compression cycle

Analysis of vapour compression refrigeration cycle can be understood by the diagram shown in the figure.

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.

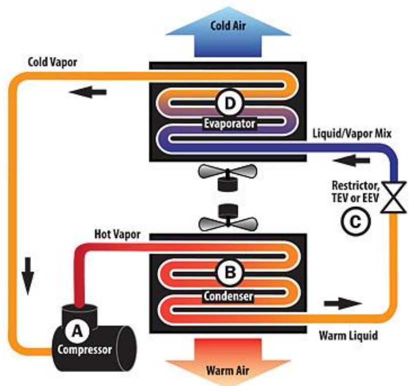

Fig. 3: Simple VCRS cycle

II. EFFECT OF SUPERHEATING AND SUB-COOLING

If the temperature of refrigerant leaving from the condenser coil is decreased by means of some external heat exchanger device which leads to add some cooling effect to refrigerant without changing the compressor work. This additional cooling process of refrigerant is called sub-cooling.

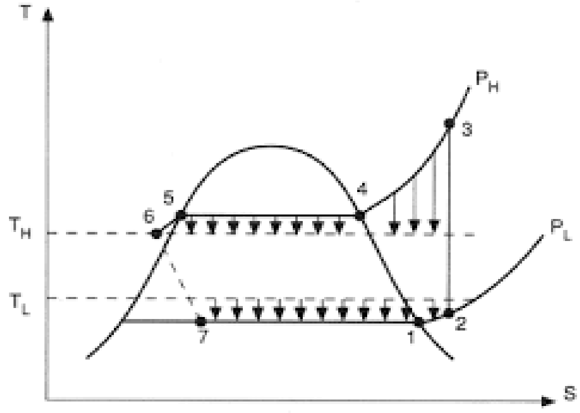

Fig. 4: T-S diagram of Sub-cooling and Superheating

Superheating refers to the heating of refrigerant vapour above saturation temperature at the outlet of the evaporator. Sub-cooling refers to the cooling of liquid refrigerant leaving the condenser. Superheating and sub-cooling is an important process in VCR system which affects the performance of VCR system. Superheating is done in order to as certain that there is no droplet of liquid refrigerant being carried over into the condenser. 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. Further, if the temperature of refrigerant leaving from the evaporator or before entering the compressor, is increased by means of external heat exchanger device that leads to reduction in compressor work. Hence, the performance of VCR system can be improved. In the present work, efforts are made to improve the performance of window air conditioning system by introducing the thermoelectric module (TEM) which provides the sub-cooling and superheating effect.

III. THERMOELECTRIC MODULE

Thermoelectric module is also known as thermoelectric cooler or Peltier cooler. Thermoelectric module consists of number of alternate p-type and n-type doped semiconductor thermo-elements, which is connected electrically in series and thermally in parallel. Thermo-electric elements are mounted between two ceramic substances. Thermo-electric module consists of regular matrix of thermo-electric elements (pellets), ceramic plates. The plates provide the mechanical integrity of a thermo-electric module. They must satisfy strict requirements of electrical insulation from an object to be cooled and the heat sink. Thermoelectric module is also known as thermoelectric cooler or Peltier cooler. Thermoelectric module consists of number of alternate p-type and n-type doped semiconductor thermo-elements, which is connected electrically in series and thermally in parallel. Thermo-electric elements are mounted between two ceramic substances. Thermo-electric module consists of regular matrix of thermo-electric elements (pellets), ceramic plates. The plates provide the mechanical integrity of a thermo-electric module. They must satisfy strict requirements of electrical insulation from an object to be cooled and the heat sink.

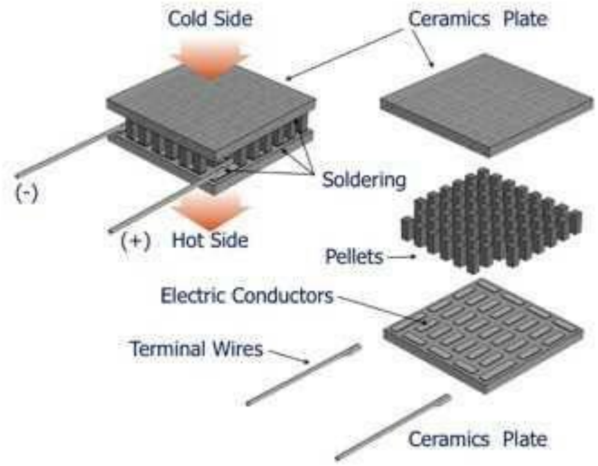

Fig. 5: Thermoelectric Module (TEM)

When DC voltage is applied to thermo-electric module, the positive and negative charges carries in the pallets array absorb heat energy from one substrate surface and release it to the opposite substrate surface. The surface from heat is absorbed becomes cold and the surface from heat is released, becomes hot. For heating and cooling purpose, thermo-electric technology is used in small laser diode coolers, portable refrigerators, scientific thermal conditioning, liquid coolers and beyond.

IV. THEORY FOR ANALYSIS

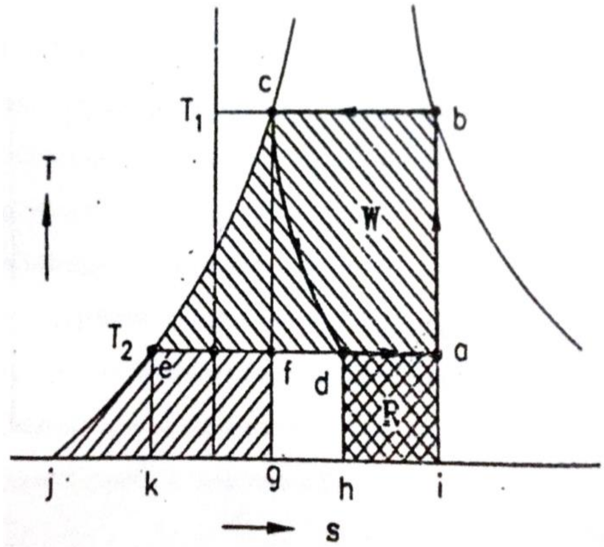

Fig.6 T-S Diagram of VCR cycle

Here assumption is made that refrigerant is dry and saturated at the end of compression, the 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

V. EXPERIMENTAL SETUP

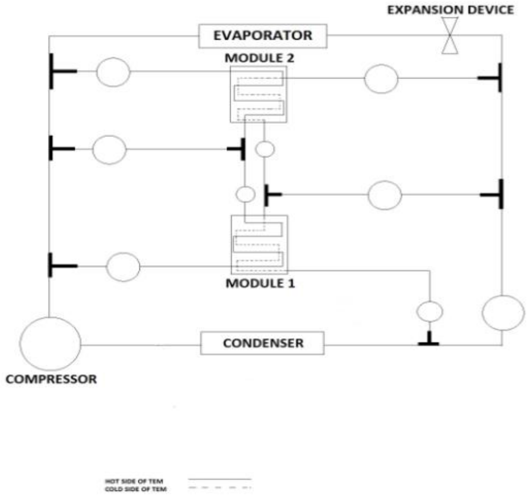

Fig. 7: Layout of experimental setup showing TEM

Fig.7 shows the layout of experimental set up and fig. 8 represents the actual experimental set up. Dotted line in fig.8 shows the cold side of thermo electric module.

Fig. 8: Experimental Set-Up

VI. COMPONENT SPECIFICATION

1) Refrigeration capacity of window air conditioning system: 1.5 TR
2) Compressor: Reciprocating type, Hermitically sealed, 1/4 HP, 230 V, 50 Hz, A.C. only 1.1 Amp. Max.
3) Refrigerant: R22 ($CHClF_2$)
4) Thermoelectric Module:
   MODEL TEC1-12706
   I_{max} = 9 amp, V_{max} = 12 volts, Power = 72 watts, ΔT_{max}= 64°C,
5) Number of thermocouple = 127, Dimensions = 40mm*40mm*3.4mm
6) Copper Plates:
   Dimensions = 300 mm *300 mm*1 mm
7) Battery:
   3 V, 6 V, 9 V & 4 amp DC supply
8) Volume of wooden casing = 0.10881 m^3

VII. 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) without TEM (2) with single TEM and (3) with single TEM. Further, the observations are recorded by supplying 3V, 6V and 9V for the case (2) and (3) as mention above.

Nomenclature

T_1=Compressor inlet temperature (°c)
T_2=Condenser inlet temperature (°c)
T_3=Capillary inlet temperature (°c)
T_4=Evaporator inlet temperature (°c)
T_5=Temperature of space to be cooled (°c)

General Readings,
Inlet pressure of Compressor, P_1 = 3.7023 bar
Outlet pressure of Compressor, P_2 = 15.8370 bar

	Voltage supply (V)	Time (min)	T_1	T_2	T_3	T_4	T_5
Without TEM		15	-4	58	38	-8	-5
With single TEM	3	15	-5	55	34	-7	-4
	6		-5	59	35	-7	-4
	9		-6	62	36	-7	-4
With Double TEM	3	15	-3	64	40	-4	-2
	6		-4	65	40	-6	-3
	9		-4	69	41	-5	-2

Table 1:

VIII. CALCULATIONS

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

A. *For without TEM*

Enthalpies for the observation,
h_2 = 272.70 kJ/kg
h_3 = 97.73 kJ/kg

1) Refrigerating Effect:

R.E. = h_1 - h_3
= 247.73 – 97.73
= 150 kJ/kg

2) Work done:

W.D. = h_2 - h_1
= 272.7 – 247.73
= 24.97 kJ/kg

3) Co-efficient of Performance:

C.O.P. = R.E/W.D.
= 150/24.97
= 6.00

4) Mass of Refrigerant:

M.O.R = (TR*210)/R.E.
= (1.5*210)/150
= 2.1 kg/min

5) Power Consumption:

P.C. = M.O.R. x (W.D.)/60
= 2.1(24.97)/60
= 0.87395 Kw

B. For with single TEM (Voltage = 3 V)

Enthalpies for the observation,
h_1 = 254.086 kJ/kg
h_2 = 281.78 kJ/kg
h_3 = 82.688 kJ/kg

1) Refrigerating Effect:

R.E. = h_1 - h_3
= 254.086 – 82.688
= 171.398 kJ/kg

2) Work done:

W.D. = h_2 - h_1
= 281.78 – 254.086
= 27.694 kJ/kg

3) Co-efficient of Performance:

C.O.P. = R.E/W.D.
= 171.398/27.694
= 6.188

4) Mass of Refrigerant:

M.O.R = (TR*210)/R.E.
= (1.5*210)/171.398
= 1.8378 kg/min

5) Power Consumption:

P.C. = M.O.R. x (W.D.)/60
= 1.8378(27.694)/60
= 0.8482 kW

C. For with double TEM (Voltage = 3 V)

Enthalpies for the observation,
h_1 = 248.86 kJ/kg
h_2 = 268.40 kJ/kg
h_3 = 100.00 kJ/kg

1) Refrigerating Effect:

R.E. = h_1 - h_3
= 248.86 – 100.00
= 148.86 kJ/kg

2) Work done:

W.D. = h_2 - h_1
= 268.40 – 248.86
= 19.54 kJ/kg

3) Co-efficient of Performance:

C.O.P. = R.E/W.D.
= 148.86/19.54
= 7.61

4) Mass of Refrigerant:

M.O.R = (TR*210)/R.E.
= (1.5*210)/148.86
= 2.116 kg/min

5) Power Consumption:

P.C. = M.O.R. x (W.D.)/60
= 2.116(19.54)/60
= 0.684 kW

IX. RESULTS

Sr. No.	Parameters	Without TEM	With Single TEM		
			3 V	6 V	9 V
1	Refrigerating Effect (kJ/kg)	150	150.1	153.4	151.13
2	Work done (kJ/kg)	24.97	23.80	31.74	28.38
3	Mass of Refrigerant (kg/min)	2.10	2.09	2.05	2.08
4	C.O.P. Of Cycle	6.00	6.31	4.83	5.33
5	Power Consumption (kW)	0.873	0.829	1.084	0.984

Table 2:

Sr. No.	Parameters	With Double TEM		
		3 V	6 V	9 V
1	Refrigerating Effect (kJ/kg)	148.86	147.73	145.46
2	Work done (kJ/kg)	19.54	25.03	30.97
3	Mass of Refrigerant (kg/min)	2.116	2.1323	2.165
4	C.O.P. Of Cycle	7.61	5.902	4.69
5	Power Consumption (kW)	0.689	0.8895	1.1178

Table 3:

X. CONCLUSION

From results it has been found that,

- The performance of window air conditioning system can be improved by introducing TEM. Form the observations, it has been found that maximum C.O.P. of air conditioning system is obtained when 3 volts is supplied to single TEM. The C.O.P.is increased by 5.16%, work done and power consumption reduced by 4.7% and 5.14% respectively with single TEM when 3 V is supplied to TEM.
- From the observations, the performance of window air conditioning system is increased when two TEM is introduced. The maximum C.O.P. of system with double TEM is also obtained when 3 volt is supplied to double TEM. The C.O.P.is increased by 26.83%, work done and power consumption reduced by 21.75% and 21.16% respectively with double TEM when 3 V is supplied to TEM.

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