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A Model Analysis of Window Air Conditioner by Introducing Thermo-Electric Module

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Abstract— With the use of conventional refrigeration system we see that life of compressor is affected by moisture particles and COP is also lower due to lower cooling capacity, there have been serious concerns shown on non conventional refrigeration system. Thermoelectric refrigeration is a type of non conventional refrigeration system. Thermoelectric module in thermoelectric refrigeration is a pretty recent development. The importance of thermo electric refrigeration was realized much later than its merits. Thermoelectric refrigeration is gaining prominence and is now widely used in several western countries. In this project, a thermoelectric module is introduced in a model of window air conditioner for sub cooling and superheating the refrigerant and it is analyzed for its effect on cooling capacity, compressor work, COP, etc.

I. INTRODUCTION

In this project, a thermoelectric module will be introduced in the model of window air conditioning for sub cooling and superheating the refrigerant and the model will be analyzed for different aspects with and without thermoelectric module.

Thermoelectric module works on the principle of “Peltier Effect”, that is when voltage potential is applied across the p-n junction ,one surface becomes colder and the opposite surface gets heated up due to conduction of heat from colder side to hotter side. This heat which is generated on the opposite side of the module is to be dissipated continuously to maintain a constant low temperature at the colder surface.

In the proposed model the evaporator coil passes over the cold side of the thermoelectric module, and then coiled around the cooling space or room to be cooled, causing the sub cooling hence increasing the cooling capacity, the out coming refrigerant from the evaporator is passed over the hot side of the module to superheat the refrigerant before entering into the compressor.

In this project by introducing of thermoelectric module, various parameters like COP, power consumption, temperature at different junction at air conditioner evaluated by comparing it with the existing air conditioner without thermoelectric module.

Refrigeration is a process of removing heat from an enclosed space or from substance and rejecting it elsewhere for primary purpose of lowering the temperature of the enclosed space or substance and maintaining that lower temperature.

Air conditioning is the cooling and dehumidification of indoor air for thermal comfort. In a broader sense, the term can refer to any form of cooling, heating, ventilation, or disinfection that modifies the condition of air.[1] An air conditioner (often referred to as AC or air con.) is an appliance, system, or mechanism designed to establish the air temperature and humidity within an area (used for cooling as well as heating depending on the air properties at a given time), typically using a refrigeration cycle but sometimes using evaporation, commonly for comfort cooling in buildings and motor vehicle.

Air conditioner air conditioner is an appliance, system, or mechanism designed to extract heat from an area via a refrigeration cycle. Air conditioner works on the same principle and use the same basic component as a refrigerator. A refrigerator uses electrical energy to transfer heat from the cool interior of a; likewise, an air conditioner uses electrical energy to transfer heat from the interior of a home to the relatively warm outside environment. In colder weather an air conditioner may be run in reverse to act as a heat pump. Air conditioners are of two main kinds: room air conditioner or window air conditioner and central air conditioners.

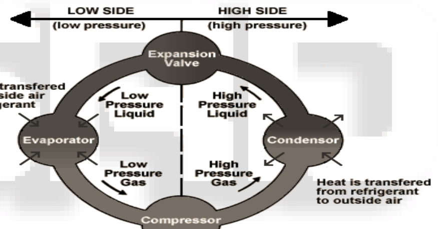

Fig. 1: A simple diagram of the refrigeration cycle

In the refrigeration cycle, a heat pump transfers heat from a lower temperature heat source into a higher temperature heat sink. Heat would naturally flow in the opposite direction. This is the most common type of air conditioning a refrigerator works in much the same way, as it pumps the heat out of the interior into the room in which it stands. This cycle takes advantage of the way phase change work, where latent heat is released at a constant temperature during a liquid/gas phase change, and varying the pressure of a pure substance also varies its condensation point.

The most common refrigeration cycle uses an electric motor to drive a compressor. in an automobile, the compressor is driven by a belt over a pulley, the being driven by the engines crank shaft (similar to the driving of the pulleys for the alternator ,power steering, etc.).Whether in a car or building, both use electric fan motors for air circulation. Since evaporation occurs when heat is released, air conditioners use a compressor to cause pressure changes between two compartments, and actively condense and pumped into the cooled compartment (the evaporator coil), where the low pressure causes the refrigerant to evaporate into the vapor, taking heat with it. In the other compartment (the condenser), the refrigerant vapor is compressed and forced through another heat exchange coil, condensing into a liquid, rejecting the heat previously absorbed from cooled space.

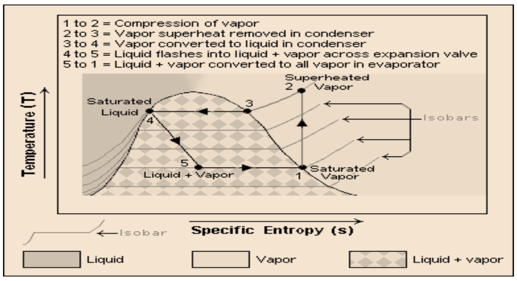

Fig. 2: Thermodynamic analysis of VCRS

The thermodynamic of vapor compression cycle can be analyzed of temperatures versus entropy diagram as depicted in figure.

At point 1 in diagram, the circulating refrigerant enters the compressor as a saturated vapor. Fro point 2 to 3, the superheated vapor travels through part of the condenser which converts the superheated vapors into saturated liquid at constant pressure.

Between point 4 and 5 the saturated liquid refrigerant passes through the expansion valve and undergoes an abrupt decrease of pressure that process result in adiabatic flash evaporation of a portion of the liquid. This process is isenthalpic.

Between point 5 and 1, the cold and partially vaporized refrigerant travels through the coil tubes in the evaporator where it is totally vaporized by a warm air (from the space being refrigerated) that the fan circulates across the coil or tubes in the evaporator The evaporator operates at essentially constant pressure the resulting saturated refrigerant vapor returns to the compressor inlet at point 1 to complete the thermodynamic cycle.

The COP of the system is given by,

COP=heat removed/work done $= (h_1-h_5)/(h_1-h_2)$

Where,

h_1=enthalpy at compressor inlet,

h_2=enthalpy at compressor outlet,

h_5=enthalpy at evaporative inlet.

In actual refrigeration cycles, the temperature of the heat sink will be several Degrees lower than the condensing temperature to facilitate heat transfer. Hence it is possible to cool the refrigerant liquid in the condenser to a few degrees lower than the condensing temperature by adding extra area for heat transfer. In such a case, the exit condition of the condenser will be in the sub cooled liquid region. Hence this process is known as sub cooling. Similarly, the temperature of heat source will be a few degrees higher than the evaporator temperature; hence the vapor at the exit of the evaporator can be superheated by a few degrees.

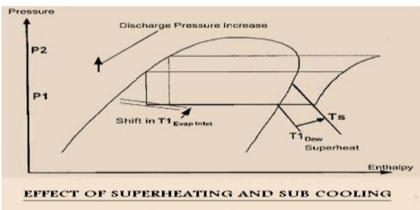

Fig. 3: effect of superheating and sub cooling

If the superheating of refrigerant takes place due to heat transfer with the refrigerated space (low temperature heat source) then it is called as useful super heating as it increase the refrigeration effect. On the other hand, it is possible for the refrigerant vapor to become superheated by exchanging heat with the surroundings as it flows through the connecting pipelines. Such a superheating is called as useless superheating as it does not increase refrigeration.

Sub cooling is beneficial as it increases the refrigeration effect by reducing the. Throttling loss at no additional specific work input. Also sub cooling ensures that only Liquid enters into the throttling device leading to its efficient operation. Useful superheating increases both the refrigeration effect as well as the work of compression. Hence the COP (ratio of refrigeration effect and work of compression) may or may not increase with superheat, depending mainly upon the nature of the working fluid. Even though useful superheating may or may not increase the COP of the system, a minimum amount of superheat is desirable as it prevents the entry of liquid droplets into the compressor.

Figure 3. shows the VCRS cycle with superheating on P-h and T-s co-ordinates. As shown in the figure, with useful superheating, the refrigeration effect, specific volume at the inlet to the compressor and work of compression increase. Whether the volume refrigeration effect (ratio of refrigeration effect by specific volume at compressor inlet) and COP increase or not depends upon the relative increase in refrigeration effect and work of compression, which in turn depends upon the nature of refrigerant used.

II. THERMOELECTRIC MODULE BASICS

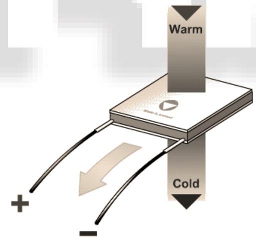

Fig. 4: T-module

The effect of heating or cooling at the junctions of two different conductors exposed to the current was named in honor of the French watchmaker Jean Peltier (1785–1845) who discovered it in 1834.It was found that if a current passes through the Contacts of two dissimilar conductors in a circuit, temperature differential appears between them. This briefly described phenomenon is the basis of thermoelectricity and is applied actively in the so-called thermoelectric cooling.

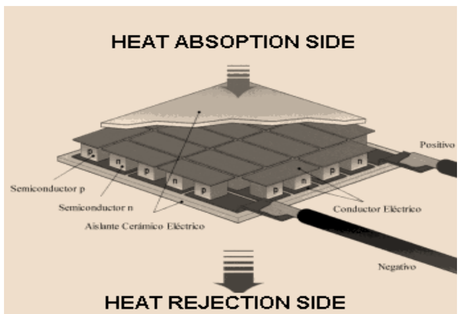

Fig. 5: Cooling and heating in T-module

When dc voltage is applied to the module, the positive and negative charge carriers in the pellet array absorb heat energy from one substrate surface and release it to the substrate at the opposite side. The surface where heat energy is released becomes hot. Using this simple approach to "heat pumping", thermoelectric technology is applied to many widely-varied applications-small laser diode coolers, portable refrigerators, scientific thermal conditioning, liquid coolers, and beyond.

Employing the effect which sees back observed, thermoelectric power generators convert heat energy to electricity .When a temperature gradient is created across the thermoelectric device, a DC voltage develops across the terminals. when a load is properly connected, electrical current flows.

Typical applications for this technology include providing power for remote tele-communication, Navigation, and petroleum installations.

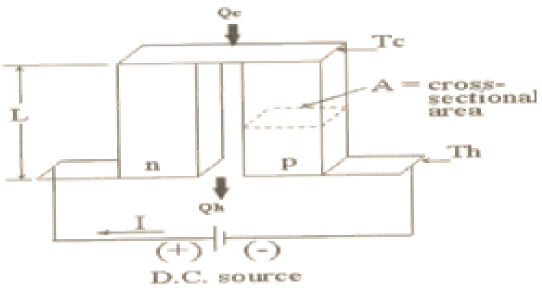

Fig. 6: P-N junction with D.C. source

Above figure 5. Represents a thermoelectric couple. It shows some terms used in mathematical equation.

Let,

L=Element Height

A=Cross Sectional Area

Q_c=Head load

T_c=Temperature of cold side

T_h=Temperature of hot side

I=Applied current

S= Seeback co-efficient

R=electrical resistivity

K=thermal conductivity

V=voltage

N=number of couples

Here are the basic equations;

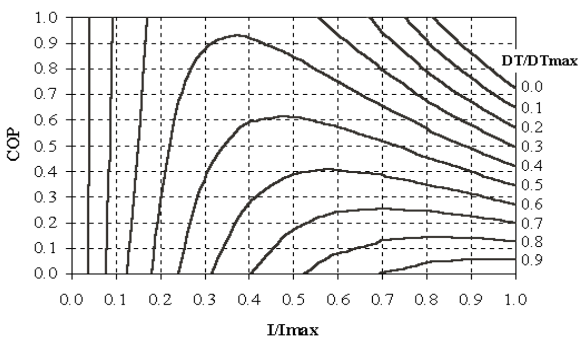

Fig. 7: COP variation with I/Imax

$$Q_c=2\times N\left[S \times I \times Tc - \left(\frac{1}{2}\right) \times I^2 \times R \times \left(\frac{L}{A}\right) - K \times \left(\frac{A}{L}\right) \times (T_h - T_c)\right]$$

$$V=2\times N\left[s \times (T_h - T_c) I \times R \times \left(\frac{L}{A}\right)\right]$$

Technically the word 'Efficiency' relates to the ratio of amount of work one gets out of machine to the amount of power input. In heat pumping application this term is rarely used because it is possible to remove more heat than the amount of power input it takes to move that heat. In such case the Efficiency would be greater than unity. For thermoelectric module it is standard to use term "co-efficient of performance" rather than Efficiency.

The COP is amount of heat pumped divided by amount of supplied electrical power. It depends on heat load, input power & the required temperature differential. Typically the COP is between 0.3 and 0.7 for single stage applications. However, COP greater than 1.0 can be achieved especially when the module is pumping against a positive temperature differential. It means when the module is removing heat from an object that is warmer than the ambient. The figure Shows normalized graph of COP ($I\backslash I_{max}$).

III. PREPARATION OF LAY-OUT AND EXPERIMENTAL SETUP LAY-OUT DIAGRAM OF WINDOW A.C. INTRODUCING THERMOELECTRIC MODULE

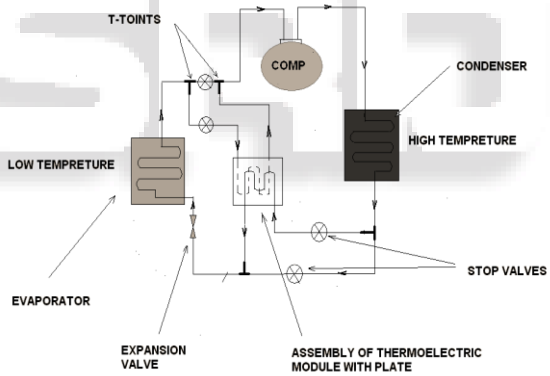

Fig. 8: Lay-out diagram

The aim of the project is to analyze, the refrigeration system of window A.C having combination of VCC as well as the thermoelectric refrigeration. As project consists of simple VCC and thermoelectric refrigeration in includes Compressor,Evaporatorcoil,Accumulator,Capillarytube,condenser, Thermoelectric module, Copper plates, Copper tubing,

The window A.C body has been purchased from market which is 15 years old but in good running condition and has capacity of 1.5TR. After selecting the window A.C., all its parts has been checked and cleaned. The tube length of the suction and discharge side has increased. The project has been designed like a test rig. In which one pass has been to pass through the modules between the capillary and the condenser this is the cold side.

Again the tube combine from the evaporator has been passed over the modules over the modules in between evaporator and compressor, this is the hot side.

T- Modules PT8- 12 -40 by MELCOR, USA. Of size 40mm* 40 mm * 3.3mm has been used. The superheating and sub cooling has been done by placing the thermoelectric modules in between the copper plates and passing the copper tubes over it which has been soldered to the plates.

Window AC capacity: - 1.5 TR
Compressor:- Reciprocating type
Refrigerant: - R-22
Thermoelectric module:- 3 nos.
Model PT8- 12-40 by MELCOR, USA.
Imax :- 8.5 amp
Vmax :- 14.4 volts
Qmax :- 72 watt
ΔTmax :- 64° C.
Number of thermocouples:- 127
Dimensions:- 40 mm * 40 mm * 3.3mm
Aluminum plates:- Dimensions:- 12 inch * 12 inch.

Fig. 9: T-Module sandwiched between Aluminum plates in Air Conditioner.

Fig. 10: T-Module sandwiched between Aluminum plates

Fig. 11: Pressure indicator with T-Valve

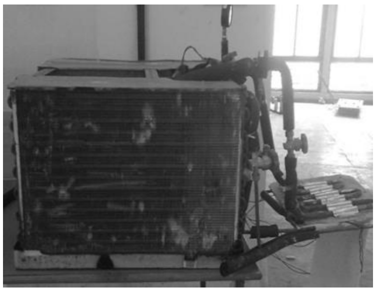

Fig. 12: Side view with T-M of Module of AC.

The Refrigerant used in this system is R-22. R-22 is a very popular refrigerant. It is colorless, almost odorless liquid with boiling point of -41^{0}C at atmospheric pressure. It is non toxic, non corrosive, none irritating and non flammable. It has relatively low latent heat values which is an advantage in small refrigerating machines. The large amount of refrigerant circulated will permit the use of less sensitive and more positive operating and regulating mechanisms. It operates at a low but positive head and back pressure with good volumetric efficiency. This refrigerant is used in many different types of industrial and commercial application such as refrigerators, freezers, water coolers, room and window air conditioners etc. Its principle use is found in reciprocating and rotary compressors.

R-22 has a pressure of 1.92 bars at -15^{0}C and pressure of 10.88 bar at 30^{0}C. The latent heat of R-22 at -15 ^{0}C is 216.5 kj/kg. The leak may be detected by soap solution, halide torch or electronic leak detectors. The addition of mineral oil to the refrigerant has no effect on its corrosive action.

IV. RESULTS AND DISCUSSION

In this chapter calculation has been done by considering actual condition of refrigerant.

Nomenclature

T_e = Evaporator outlet temperature
T_1‘= saturation temperature at evaporator pressure
T_1 = Compressor inlet temperature
T_2 = Compressor outlet temperature
T_c = Condenser outlet temperature
$T_{3'=}$saturation temperature at condenser pressure
T_3 = sub cooled outlet temperature
T_4 = Evaporator inlet temperature
T_5 = Room temperature
T1= compressor outlet temperature
T2= evaporator inlet temperature

General readings
Atmospheric temperature T_a = 33.7 °C
Inlet pressure of compressor P1 = 4.24 bar
Outlet pressure of compressorP2 = 18.55 bar
Specific heatC_{pv1}=0.723 kJ/kg K
C_{pv2}= 1.102 kJ/kg K
C_{pl2}= 1.39 kJ/kg K

A. Without thermoelectric module

1) Observation table

Time (min)	T_e (°C)	T_1 (°C)	T_2 (°C)	T_c (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)
5	22.3	23.1	84.1	44.0	43.0	10.6	33.8
10	23.6	23.3	84.9	45.0	42.9	10.4	33.8
15	22.9	23.1	86.1	46.7	43.0	9.4	33.8

Table. 1: Temperature variation Without T-Module

2) Calculation

Refrigerating effect
R.E. $=h_1-h_3$
=166.93 kJ/kg
Work Done = (T.R. * 210)/ R.E.
=34.23 kJ/kg
COP =R.E. / W.D.
= 4.87
Mass of Refrigerant M=(T.R. * 210) / R.E.
=1.88kg

Power Consumption
=M (W.D)
=64.59 kJ

B. With Thermoelectric Module Voltage Supply = 3 V

1) Observation table

Time (min)	T_e (°C)	T_1 (°C)	T_2 (°C)	T_c (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)
5	23.1	30.4	86.4	46.6	39.9	11.2	33.8
10	25.9	29.0	86.3	45.3	41.1	11.7	33.8
15	26.3	31.1	85.0	43.0	40.2	12.1	33.8

Table. 2: Temperature variation With T-Module(3V)

2) Calculation

REFRIGERATING EFFECT
R.E. =171.25 kJ/kg
Work done= 34.87 kJ/kg
COP= 4.92
Power Consumption= 64.16 kJ

C. With Thermoelectric Module Voltage Supply = 6 V

1) Observation table

Time (min)	T_e (°C)	T_1 (°C)	T_2 (°C)	T_c (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)
5	27.0	29.1	85.6	45.2	42.0	12.0	33.8
10	26.5	29.2	84.2	44.8	41.9	12.1	33.8
15	27.1	30.2	86.4	45.6	41.8	11.6	33.8

Table. 3: Temperature variation With T-Module(6V)

2) Calculation

REFRIGERATING EFFECT
R.E. = 175.97 kJ/kg
Work done= 35.12 kJ/kg
COP=5.02
Power Consumption= 63.21 kJ

D. With Thermoelectric Module Voltage Supply = 9 V

1) Observation table

Time (min)	T_e (°C)	T_1 (°C)	T_2 (°C)	T_c (°C)	T_3 (°C)	T_4 (°C)	T_5 (°C)
5	24.0	25.0	82.2	46.6	41.2	12.0	33.8
10	25.5	27.5	87.0	44.2	41.5	12.2	33.8
15	25.8	28.2	86.7	43.8	41.3	11.4	33.8

Table. 4: Temperature variation With T-Module(9V)

2) Calculation

REFRIGERATING EFFECT
R.E. = 179.13 kJ/kg
Work done= 35.86 kJ/kg
COP= 4.99
Power Consumption= 63.06 kJ

V. CONCLUSION

After performing the experiment and comparing the result of simple setup and setup by introducing thermoelectric module we find that there change in parameters. Results are beneficial.

Sr. No	Parameters	Without TEM	With TEM		
			3V	6V	9V
1	Refrigerating Effect(kJ/ kg)	166.93	171.25	175.97	179.13
2	Workdone (kJ/kg)	34.23	34.87	35.12	35.86
3	COP of cycle	4.87	4.92	5.02	4.99

Experiment investigation reveals that There was Improvement in Refrigerating effect, Work Done of Compressor and C.O.P on Supply of 3V and 6V than that of decrease on Supply on 9V.

From a result we can conclude that with introduction of thermoelectric module refrigeration effect and cop increases and compressor work reduces as compared to simple arrangement in which cop and refrigeration effect is low and compressor is higher.

Also in the setup of cycle with T-module cop, Refrigeration effect and work done optimized when 6 volt is applied to thermoelectric module compared to 3 volt and 9 volt.

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