Performance Measurement of Domestic Refrigerator by Introducing Thermoelectric Module

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Abstract— In current scenario, energy crisis is the bottleneck for the growth of the nation. For the growth of the nation, as it depends on the electricity generation and demand, there is a two ways either generation of more electricity or saving of electricity. By the current project, we may move one step forward to save the electrical energy. In the current project, we are going to introduce thermoelectric module, working on Peltier Effect, in the existing domestic refrigerator system and it is expected that the power consumption may reduce. We will prepare working model of domestic refrigeration system by introducing thermoelectric module which provides additional sub-cooling and superheating effect in the system.
(1) Without thermoelectric module
(2) With thermoelectric module.
From the observation of experiment, we will calculate the refrigeration effect, work supply and C.O.P. of refrigeration system. Then after, we will perform an experiment on the working model for the case

Key words: Energy Crisis, Refrigeration Effect, Thermoelectric Module

I. Introduction

Domestic refrigerator is a common household appliance that consists of a thermally insulated compartment and a heat pump that transfer heat from the inside of fridge to its external environment so that the inside of the fridge is cooled to a temperature below the ambient temperature of the room. [1] [2]

It also consists of the following four basic components:

- Evaporator
- Compressor
- Condenser
- Expansion device

It works on Vapour compression refrigeration cycle.

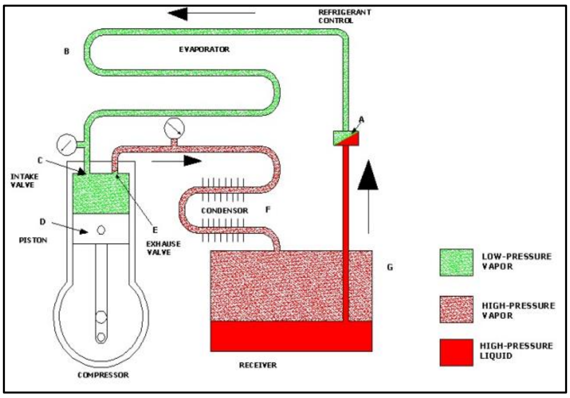

Fig. 1: Simple VCRS Cycle [9]

Effect of superheating and sub cooling

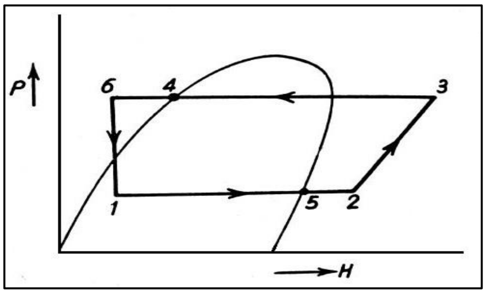

Fig. 2: P-H Diagram with Subcooling and Superheating

The superheating of Vapour before entering into the compressor and sub cooling of liquid before entering into in expansion valve is shown in fig. where 5-2 represent the superheating and 4-6 represent undercooling.

Superheating is done in order to as certain that there is no droplet of liquid refrigerant being carried over into the compressor. A small degree of sub cooling of liquid refrigerant after the condenser is also used to reduce the mass the vapour format during expansion, so that too many vapour bubbles do not impede the flow of liquid refrigerant through the expansion valve.

Both the superheating of vapour at the evaporator outlet and the sub cooling of the liquid at the condenser outlet contribute to an increase in refrigerating effect .The compressor discharge temperature increases due to superheat, and the load on the load on condenser also increases.

Sometimes, a liquid line heat exchanger is used in the plantain which the liquid is sub cooled in the heat exchange, reducing the load on the condenser and improving the C.O.P.

Heat extracted from the space = h3 – h1
Work done = h3 – h2
C.O.P. = h2 – h1/h3 – h2 [3] [4]

II. Thermoelectric Module

A Thermoelectric module also called thermoelectric cooler or Peltier cooler, is a semiconductor based electronic component that functions as a small heat pump.

By applying a low voltage DC power to a thermoelectric module from one side to other. One module face, therefore, will be cool while the opposite face is simultaneously heated. It is important to note that this phenomenon may be reversed whereby a change in polarity (plus and minus) of the applied DC voltage will cause heat to be moved in the opposite direction. Consequently, a thermoelectric module may be used for both heating and cooling thereby making it highly suitable for precise temperature control application. A Thermoelectric Module can also be used for power generation. [5] [6] [8]

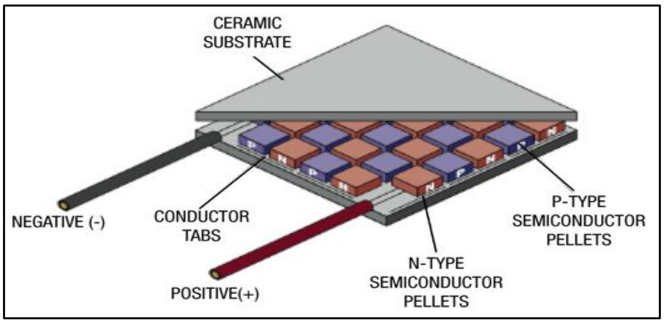

Fig. 3: Thermoelectric Module (TEM) [6]

III. THEORY OF ANALISIS

When the Vapour is wet after at the end of compression, work done and refrigeration effect is calculated as given below.

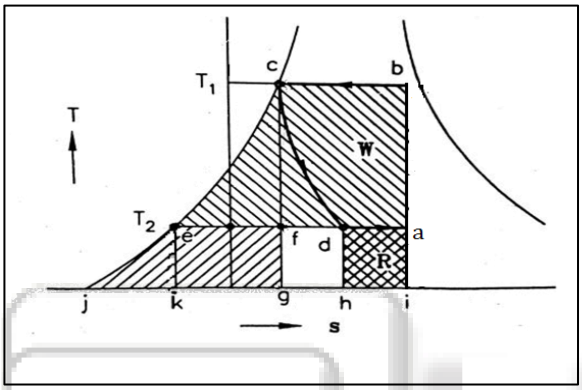

Fig. 4: T-S Diagram

W (workdone)= Area 'abcea'= hb – ha

R (Refrigeration effect) = Area 'adhia'

= ha – hd

= ha – hc as hd =hc

C.O.P =R/W=(ha – hc)/(hb – ha) [1] [3]

IV. EXPERIMENT SETUP

Layout diagram for domestic refrigerator introducing thermoelectric module

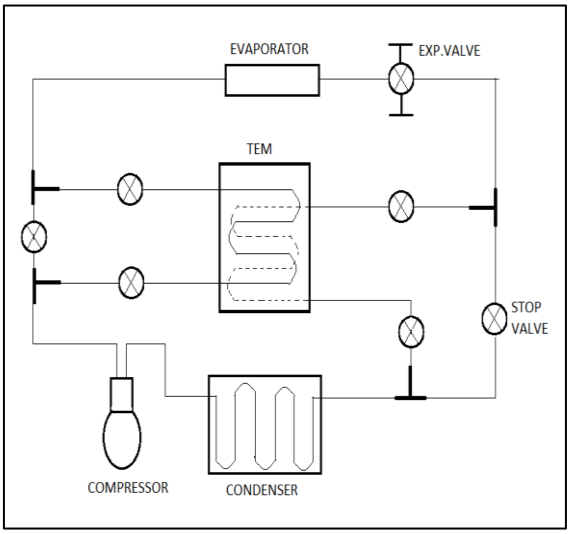

Fig. 5: Layout Showing TEM & Valve Arrangement

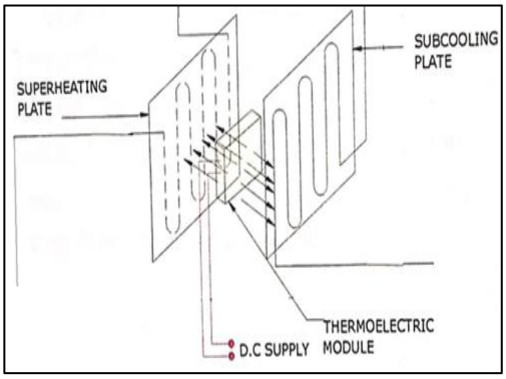

Fig. 6: TEM between Two Copperplates

Fig. 7: Experimental Set-Up

V. COMPONENT SPECIFICATION

A. Refrigerator Capacity:

165 liters

B. Compressor:

Reciprocating type

- Hermitically sealed
- 1/8 HP, 230 VOLT, 50 Hz,
- A.C. Only 1.1 Amp. Max.

C. Refrigerant: R12 (CCL2F2)

D. Thermoelectric Module:

MODEL PT8-12-40 by MELCOR,USA

- Imax: 6 amp
- Vmax: 12 volts
- Qmax: 72 watts
- ΔTmax: 64°C
- Number of thermocouples: 127
- Dimensions: 40mm * 40mm * 3.3mm

E. Copper plates:

– Dimensions: 6inches * 6inches * 2mm

F. Adaptor:

– 0-12 volts, variable

VI. ANALYSIS CALCULATION CONSIDERING ACTUAL CONDITIONS

All calculations has been done by considering the conditions of refrigerant. We take temperatures and pressures of different point on cycle at interval of five minute. Here observation table of fifth reading (after 25 minute) is given.

	Comp Outlet	Conden Outlet	Evap Coil	Cold side		Hot side	
Time min.	T_2 (°C)	T_3 (°C)	T_1 (°C)	Inlet (°C)	Outlet (°C)	Inlet (°C)	Outlet (°C)
25	49.6	35.8	6.7	-	-	-	-

Table 1: Without Thermoelectric Module

– Inlet pressure of compressor, P1 = 0.3915 bar
– Outlet pressure of Compressor, P2 = 13.70 bar

	Comp Outlet	Conden Outlet	Evap Coil	Cold side		Hot side	
Time min.	T_2 (°C)	T_3 (°C)	T_1 (°C)	Inlet (°C)	Outlet (°C)	Inlet (°C)	Outlet (°C)
25	49.6	35.8	6.7	-	-	-	-

Tabal 2: With Plates and Without TEM

– Inlet pressure of compressor, P1 = 0.783bar
– Outlet pressure of Compressor, P2 = 14.094 bar

	Comp Outlet	Conden Outlet	Evap Coil	Cold side		Hot side	
Time min.	T_2 (°C)	T_3 (°C)	T_1 (°C)	Inlet (°C)	Outlet (°C)	Inlet (°C)	Outlet (°C)
25	46.3	35.6	2.5	38.4	33.1	32.6	32.7

Table 3: with Thermoelectric Module (1.5 Volts)

– Inlet pressure of compressor, P1 = 0.8613bar
– Outlet pressure of Compressor, P2 = 14.094 bar

	Comp Outlet	Conden Outlet	Evap Coil	Cold side		Hot side	
Time min.	T_2 (°C)	T_3 (°C)	T_1 (°C)	Inlet (°C)	Outlet (°C)	Inlet (°C)	Outlet (°C)
25	48.2	33.4	5.6	35.6	33.1	32.6	32.9

Table 4: With Thermoelectric Module (3 Volts)

– Inlet pressure of compressor, P1 = 0.8613bar
– Outlet pressure of Compressor, P2 = 14.094 bar

	Comp Outlet	Conden Outlet	Evap Coil	Cold side		Hot side	
Time min.	T_2 (°C)	T_3 (°C)	T_1 (°C)	Inlet (°C)	Outlet (°C)	Inlet (°C)	Outlet (°C)
25	50.6	33.8	5.1	35.8	32.2	31.9	32.6

Table 5: With Thermoelectric Module (6 Volts)

– Inlet pressure of compressor, P1 = 0.8613bar
– Outlet pressure of Compressor, P2 = 14.094 bar

1) Calculation (Without TEM)

Taking fifth reading of the observation. Using p-h chart of R12.
h1 = 191.79 kJ/kg
h2 = 215 kJ/kg
h3 = 70.4 kJ/kg
Refrigerating effect
R.E. = h1 – h3
=191.79 – 70.4
=121.39
Mass of refrigerant
M.R. =14000/(R.E.)
= 14000/121.39
= 115.33 kg/hr.-tonne
Work done
W.D. = h2 – h1
= 215 – 191.79
= 23.21 KJ/kg.
C.O.P. = (R.E.)/(W.D.)
=121.39/(19.8018)
=5.23
Power Consumption
= (M.R.* W.D.)/3600
= (115.33*23.21)/3600
= 0.7435 kW/tonne

2) Calculation (With TEM 6 volts)

Taking fifth reading of the observation. Using p-h chart of R12.
h1 = 194.7 kJ/kg
h2 = 215.2 kJ/kg
h3 = 66.70 kJ/kg
Refrigerating effect
R.E. = h1 – h3
=194.7 – 66.70
=128 kJ/kg
Mass of refrigerant
M.R. =14000/(R.E.)
= 14000/128
= 109.38 kg/hr.-tonne
Work done
W.D. = h2 – h1
= 215.2 – 194.7
= 20.5 KJ/kg.
C.O.P. = (R.E.)/(W.D.)
=128/(20.5)
=6.24
Power Consumption
= (M.R.* W.D.)/3600
= (109.38*20.5)/3600
= 0.6228 kW/tonne [3] [11]

VII. RESULT

Sr. No.	Parameters	Without TEM	With plates & No TEM	With TEM		
				1.5 V	3 V	6 V
1	Refrigerating effect(kJ/kg)	121.39	119.82	125.79	126.84	128
2	Work done(kJ/kg)	23.21	23.63	20.55	20.7	20.5
3	C.O.P	5.23	5.07	6.12	6.12	6.24

4	Mass of refrigerant(kg/hr.tonne)	115.33	116.84	111.29	110.54	109.38
5	Power consumption (kw/tonne)	0.7435	0.7669	0.6352	0.6356	0.6228

Table 6: Results

VIII. CONCLUSION

From the different calculation shown in previous chapter the following conclusion can be attained.

1) From the actual calculation we can get desired result. The refrigeration effect is increase, work done by compressor is decrease, mass flow rate is decrease, power consumption is decrease and C.O.P is increase by introducing of TEM.
2) We can see that result are positive for thermoelectric refrigerator. We can see that the C.O.P without thermoelectric module is 5.23. With the application of 1.5v to the thermoelectric module the COP is 6.12, with application of 3v the COP is 6.12 and with application of 6v C.O.P is 6.24.
3) We can see that by introducing of TEM we can get instant cooling. From the readings without TEM temperature 10.8°C attained by refrigerator in five minute. By introducing of TEM temperature 5.9°C attained by refrigerator in five minute at 1.5v, temperature 7.3°C attained by refrigerator in five minute at 3v and temperature 6.3 °C attained by refrigerator in five minute 6v.
4) TEM operate in DC voltage (1-12v) so Power consumed by TEM is very less. This power is neglected compered to increasing Refrigeration effect and decreasing power consumption with the help of it.

IX. FUTURE SCOPE

One may get more positive result if some steps given below should taken in preparing the experimental setup. 1)

1) Select the module of higher capacity.
2) Use two or three module in group between single pair of copper plate.

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