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PERFORMANCE COMPARISION OF VCR SYSTEM WITH CONVENTIONAL AND HEXAGONAL CONDENSER USING R134a & R600a AS REFRIGERANTS

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Abstract

Most of the household refrigerators work on the vapour compression refrigeration system which has high coefficient of performance. The system mainly consists of components like compressor, condenser, expansion value, capillary tube and evaporator. The pressure gauges and temperature indicate joints are integrated with the system at appropriate positions. The performance of the system depends upon the performance of all the components of the system. The main objectives of this paper is to find coefficient of performance of the refrigeration system using conventional condenser and then verifying effect of performance using hexagonal condenser made of copper material on Godrej refrigerator of refrigeration capacity 165 lts hermetic sealed compressor unit with R134a & R600a as refrigerants.

The purpose of the paper is to make two performance comparisons. Namely:

First: The objective of this experiment is to compare the vital performance parameters between conventional zig- zag type condenser and the Hexagonal condenser. The refrigerant adopted to carry out this experiment is R134a. The main purpose of using Hexagonal shaped condenser is to increase the surface area of condenser which in turn increases the heat transfer.

Second: The objective of this experiment is to compare the vital performance parameters between two refrigerants R134a and R600a using VCR system equipped with Hexagonal condenser.

The designed coil condenser plays a very important role in the performance of a vapour compression refrigeration system. Hence experimental investigations are the best in terms of optimization for certain design parameters. Finally an attempt is made to verify the performance of the system. It is observed that by changing the conventional design to Hexagonal shaped condenser, the performance of the refrigeration system is increased.

I. INTRODUCTION

The term "***refrigeration***" may be defined as the process of removing heat from a substance under controlled conditions. It also includes the process of reducing and maintaining the temperature of a body below the general temperature of its surroundings. In other words, the refrigeration means a controlled extraction of heat from a body whose temperature is already below temperature of its surroundings. In a refrigerator, heat is virtually pumped from a lower temperature to a higher temperature. According to second Law of thermodynamics, this process can only be performed with the aid of some external work. It is thus obvious that supply of power is regularly required to drive a refrigerator. Theoretically, a refrigerator is a reversed heat engine or a heat pump which pumps heat from a cold body and delivers it to a hot body. The substance which works in a pump to extract heat from a cold body and to deliver it to a hot body is known as refrigerant.

Vapour compression cycle is an improved type of air refrigeration cycle in which a suitable working substance (other than the air), termed as refrigerant, is used. The refrigerants generally used for this purpose are ammonia (NH3), carbon dioxide (CO2) and sulphur-dioxide (SO2) for industrial and Freon (HFC R134a) for domestic refrigeration.
Basic components of a vapour compression refrigeration system are shown in fig. 1 they are,

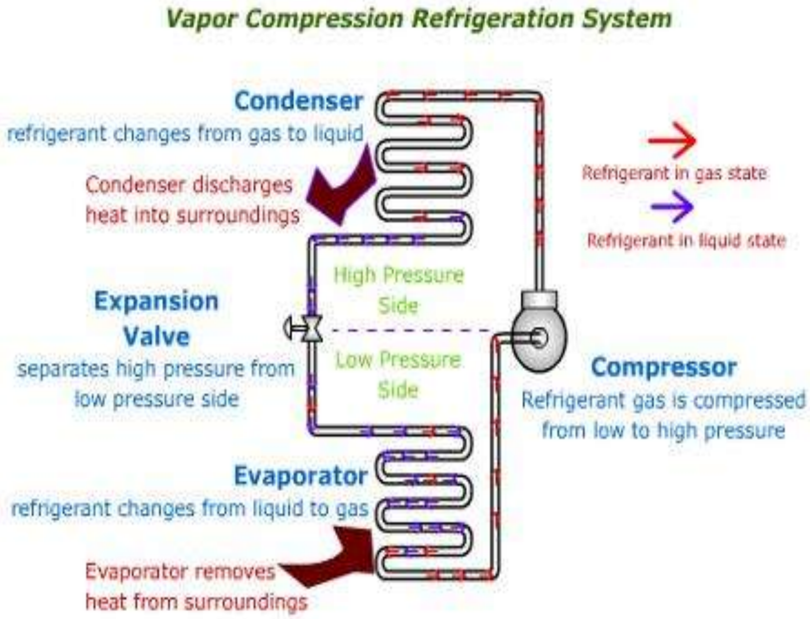

Fig.1.1 Vapour compression refrigeration system

- Compressor: It is motor driven, it sucks vapour refrigerant from evaporator and compresses.
- Condenser: High pressure vapour refrigerant is condensed into liquid form in the condenser using cooling medium such as water.
- Expansion Valve: High pressure refrigerant is throttled down to evaporator pressure; rate of flow is metered.
- Evaporator: A cooling chamber in which products are placed, low pressure liquid refrigerant flows in the coils of evaporator and absorbs heat from products, the refrigerant vaporizes and leaves for compressor.

II. EXPERIMENTAL WORK

In vapour compression refrigerating system basically there are two heat exchangers. One is to absorb the heat which is done by evaporator and another is to remove heat absorbed by refrigerant in the evaporator and the heat of compression added in the compressor and condenses it back to liquid which is done by condenser. This paper focuses on heat rejection in the condenser this is only possible either by providing a fan or extending the surfaces. The extended surfaces are called fins. The rate of heat rejection to the condenser depends upon the number of fins attached to the condenser. This paper investigated the performance of condenser using hexagonal shape condenser in the present domestic refrigerator and copper material fins are used. The performance of the condenser will also help to increase COP of the system. The performance of the condenser is investigated by using conventional condenser with Hexagonal shaped condenser and the refrigerant as R134a. The performance is also evaluated by changing the refrigerants R134a to R600a with Hexagonal shaped condenser.

In order to know the performance characteristics of the vapour compression refrigerating system the temperature and pressure gauges are installed at each entry and exit of the component. Experiments are conducted on hexagonal condenser having fins. Different tools are also used like snips to cut the plated fins to required sizes, tube cutter to cut the tubes and tube bender to bend the copper tube to the required shape and angle. Finally the condenser is fabricated to the suitable way for the requirement. All the values of pressures and temperatures are tabulated which are required to estimate the COP of the refrigeration system.

III. EXPERIMENTAL SETUP:

Domestic refrigerator selected for the project has the following specifications:

Refrigerant used: R134a & R600a

Capacity of the refrigerator: 165 lts

Compressor capacity: 0.14H.P

Speed: 2850rpm

Condenser coil dimensions:

Length - 9100mm

Diameter - 6.4mm

Evaporator coil dimensions:

Length - 7600mm

Diameter - 6.4mm

Capillary tube dimensions:

Length - 3600mm

Diameter - 0.9mm

Fig.3.1 Conventional shaped condenser coil Experimental setup

Fig.3.2 Hexagonal shaped condenser coil

Fig.3.3 Hexagonal shaped condenser coil Experimental setup front view

Fig.3.4 Hexagonal shaped condenser coil experimental setup side view

The following procedure is adopted for experimental setup of the vapour compression refrigeration system:

The domestic refrigerator is selected, working on vapour compression refrigeration system. Pressure and temperature gauges are installed at each entry and exit of the components. Flushing of the system is done by pressurised nitrogen gas. R134a & R600arefrigerants is charged in to the VCR system by the following process:

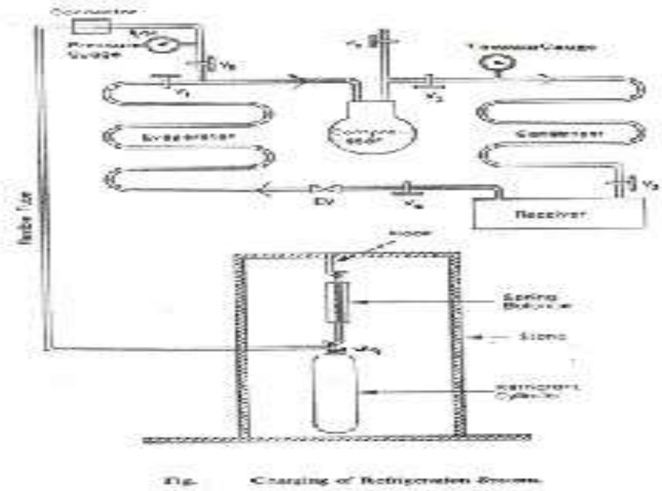

Fig.3.5 charging of the refrigeration system

The systematic line diagram for charging is shown in above figure it is necessary to remove the air from the refrigeration unit before charging. First the valve V2 is closed and pressure gauge P2, vacuum gauge V are fitted as shown in figure the valve V5 is also closed and valves V1, V4, V6 and V3 are opened and the motor is started thus the air from the condenser, receiver, and evaporator is sucked through the valves V1 and it is discharged in to atmosphere through the valve V6 after compressing it in the compressor and the vacuum gauge V indicates sufficiently low vacuum when most of the air is removed in the system. The vacuum reading should be at least 74 to 75 cm of Hg. If the vacuum is retained per above an hour it may be concluded that the system is free from the air. After removing the air the compressor is stopped and valves V1 and V6 are closed, the valves V5, V2 and V7 of the refrigerant cylinder are opened and then the compressor is started whenever the sufficient quantity of refrigerant is taken in to the system which will be noted in the pressure gauges. The compressor is stopped. The valves V7 and V5 are closed and valve V1 is opened the refrigerant cylinder is disconnected from the system the pressure gauge is used to note the pressure during the charging the system.

Leakage tests are done by using soap solution. In order to further test the condenser and evaporator pressure and check purging daily for 12 hours and found that there is no leakages which required the absolutely the present investigation to carry out further experiment. Switch on the experimental refrigerator setup and observation required for 2 hour and take the pressure and temperature readings at each section. The performance of the existing system is investigated with the help of temperature and pressure gauge readings.

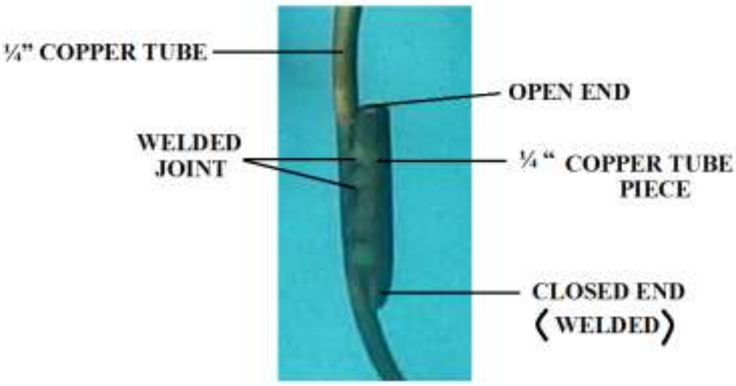

Fig.3.6 Arrangement for the temperature indication

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Fig.3.7 High pressure and Low pressure Gauges

IV. PERFORMANCE CALCULATION

4.1 Conventional condenser values:

Temperatures:

Compressor suction temperature T_1=20^{0}C

Compressor discharge temperature T_2=50^{0}C

Condenser coil out temperature T_3=35^{0}C

Evaporator coil temperature T_4=-4^{0}C

Pressures:

Compressor suction pressure P_1=1.8 bar

Compressor discharge pressure P_2=12.05 bar

Condenser pressure P_3=12.05 bar

Evaporator pressure P_4=1.8 bar

Enthalpies:

h1 = 394 KJ/Kg

h2 = 426 KJ/Kg

h3 = 270 KJ/Kg

h4 = 270 KJ/Kg

Calculations:

1. Coefficient of performance = $\frac{Refrigerant\ effect}{work\ done}$

Refrigerant effect (R.E) = h1- hf3 (or) h1- h4

= 394-270= 124 KJ/Kg

Work done (W) = h2- h1

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= 426-394= 32 KJ/Kg

∴ Coefficient of performance $= \frac{h1-hf3}{h2-h1} = \frac{124}{32}$

∴ C.O.P = 3.87

2. Mass flow rate to obtain one TR, (m_r) = $\frac{210}{Refrigerating\ effect}$

$= \frac{210}{394-270}$ = 1.693 Kg/min

3. Heat equivalent of work of compression per TR = m_r X (h2- h1)

= 1.693 x (426-394)

= 54.17 KJ/Kg

4. Heat to be rejected in condenser = h2- h3

= 426-270 = 156 KJ/Kg

5. Theoretical power of compressor =54.17/60
= 0.902 KW
6. Heat rejection per TR = (210/NRE)X (h2- h3)
= 1.693 X 156 = 264.108 KJ/min
7. Heat rejection ratio = 264.108/210
= 1.257
8. Compression pressure ratio = $\frac{Discarge\ pressure}{Suction\ pressure}$ = 12.05/1.8 = 6.69

4.2 Hexagonal shaped condenser values using refrigerant R134a:

Temperatures:

Compressor suction temperature T_1=3.3^{0}C
Compressor discharge temperature T_2=52.1^{0}C
Condenser coil out temperature T_3=44.1^{0}C
Evaporator coil temperature T_4=-9.4^{0}C

Pressures:

Compressor suction pressure P_1=1.8 bar
Compressor discharge pressure P_2=12.05 bar
Condenser pressure P_3=12.05 bar
Evaporator pressure P_4=1.8 bar

Enthalpies:

h1 = 393 KJ/Kg

h2 = 417 KJ/Kg
h3 = 260 KJ/Kg
h4 = 260 KJ/Kg

Calculations:

1. Coefficient of performance = $\frac{Net\ Refrigerant\ effect}{work\ done}$

Net Refrigerant effect (NRE) = h1- hf3 (or) h1- h4
= 393-260= 133 KJ/Kg

Work done (W) = h2- h1
= 417-393= 24 KJ/Kg

∴ Coefficient of performance = $\frac{h1-hf3}{h2-h1} = \frac{133}{24}$

∴ C.O.P = 5.542

2. Mass flow rate to obtain one TR, (m_r) = $\frac{210}{Net\ Refrigerating\ effect}$

= $\frac{210}{393-260}$ = 1.58 Kg/min

3. Heat equivalent of work of compression per TR = m_r X (h2- h1)

= 1.58 x (417-393)

= 37.92 KJ/min

4. Heat to be rejected in condenser = h2- h3

= 417-260 = 157 KJ/Kg

5. Theoretical power of compressor =37.92/60
= 0.632 KW
6. Heat rejection per TR = (210/NRE)X (h2- h3)
= 1.58 X 157 = 248.08 KJ/min
7. Heat rejection ratio = 248.08/210
= 1.181
8. Compression pressure ratio = $\frac{Discarge\ pressure}{Suction\ pressure}$ = 12.05/1.8 = 6.69

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4.3 Hexagonal shaped condenser values using refrigerant R600a:

Temperatures:

Compressor suction temperature $T_1=13^0C$

Compressor discharge temperature $T_2=47^0C$

Condenser coil out temperature $T_3=41^0C$

Evaporator coil temperature $T_4=-11.2^0C$

Pressures:

Compressor suction pressure P_1=1.69 bar

Compressor discharge pressure P_2=11.56 bar

Condenser pressure P_3=11.56 bar

Evaporator pressure P_4=1.69 bar

Enthalpies:

h1 = 389 KJ/Kg

h2 = 415 KJ/Kg

h3 = 258 KJ/Kg

h4 = 258 KJ/Kg

Calculations:

1. Coefficient of performance = $\frac{Net\ Refrigerant\ effect}{work\ done}$

Net Refrigerant effect (NRE) = h1- hf3 (or) h1- h4
= 389-258= 131 KJ/Kg

Work done (W) = h2- h1
= 415-389= 26 KJ/Kg

∴ Coefficient of performance $= \frac{h1-hf3}{h2-h1} = \frac{131}{26}$

∴ C.O.P = 5.03

2. Mass flow rate to obtain one TR, (m_r) = $\frac{210}{Net\ Refrigerating\ effect}$

$= \frac{210}{389-258}$ = 1.60 Kg/min

3. Heat equivalent of work of compression per TR = m_r X (h2- h1)

= 1.60 x (415-389)

= 41.6 KJ/min

4. Heat to be rejected in condenser = h2- h3

   = 415-258 = 157 KJ/Kg
5. Theoretical power of compressor =41.6/60
   = 0.693 KW
6. Heat rejection per TR = (210/NRE)X (h2- h3)
   = 1.60 X 157 = 251.2 KJ/min
7. Heat rejection ratio = 251.2/210
   = 1.196
8. Compression pressure ratio = $\frac{Discarge\ pressure}{Suction\ pressure}$ = 11.56/1.69 = 6.84

V. RESULTS AND DISCUSSION:

Table.1 Comparison of performance parameter

Performance parameter	Conventional condenser coil			Hexagonal shaped condenser coil with R134a			Hexagonal shaped condenser coil with R600a		
	1	2	3	1	2	3	1	2	3
COP	3.87	3.69	3.63	5.542	5.41	5.22	5.03	4.87	4.59
Heat rejection in condenser KJ/Kg	156	155	153	157	157	157.3	157	156	155
Theoretical power of compressor (KW)	0.902	0.89	0.82	0.632	0.618	0.607	0.693	0.686	0.653
Net refrigerating effect(kJ/Kg)	124	122	120	133	132.5	132	131	131.5	130

The experiment was conducted on a vapour compression refrigeration system with Hexagonal shaped condenser coil and the refrigerants are R134a & R600a. Based on the recorded data, the thermo physical properties with respect to effect of evaporator temperature, work of compression, evaporator load on refrigeration effect and mass flow rate, work of compression on actual COP were calculated and the results are discussed below and graphically plotted.

5.1 Effect of the condenser coil on Coefficient of performance:

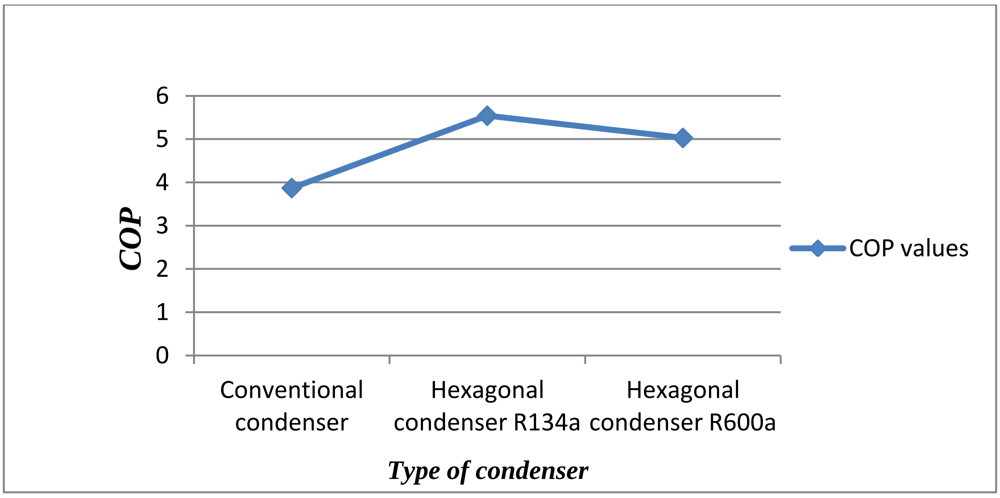

Fig.5.1 COP vs. Type of condenser

From the graph and results it is absorbed that, the cooling temperature is inversely proportional to time. As the difference in evaporator temperature is high, the cooling efficiency of the system increases. Comparing the graph Hexagonal shaped condenser with R134a gives highest COP than conventional condenser & hexagonal condenser with R600a. Finally it is absorbed that COP increased by 17%. This reflects the common fact that is Hexagonal condenser with R134a is better than conventional & hexagonal condenser with R600a for condensation.

5.2 Effect of the condenser coil on Theoretical work of compression:

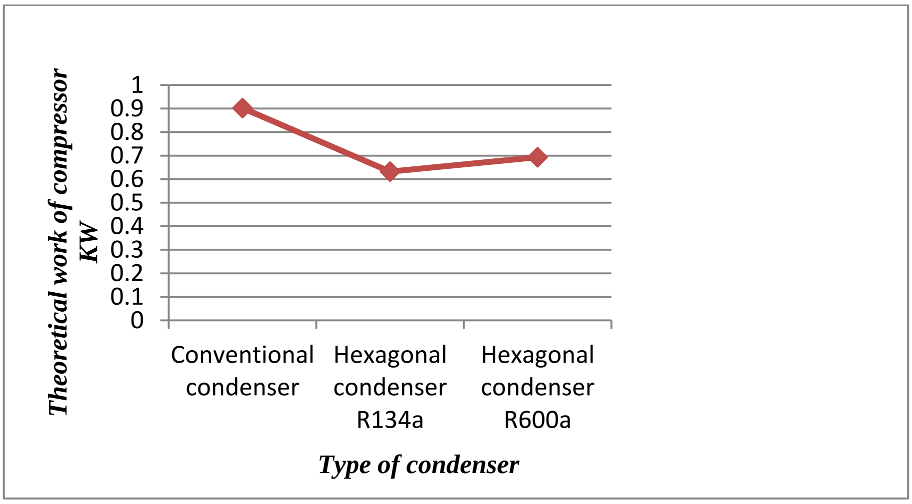

Fig.5.2 Theoretical work of compressor vs. Type of condenser

The work of compression is dependent on the suction pressure and temperature. It is evident

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from above fig 5.2 that, hexagonal condenser coil system required less work of compression when compared to conventional system. This could be a compatible and more efficient with the new design. From the results and graph showing that, the theoretical work is decreased by 17.13%.

5.3 Effect of the condenser coil on Heat rejection in condenser:

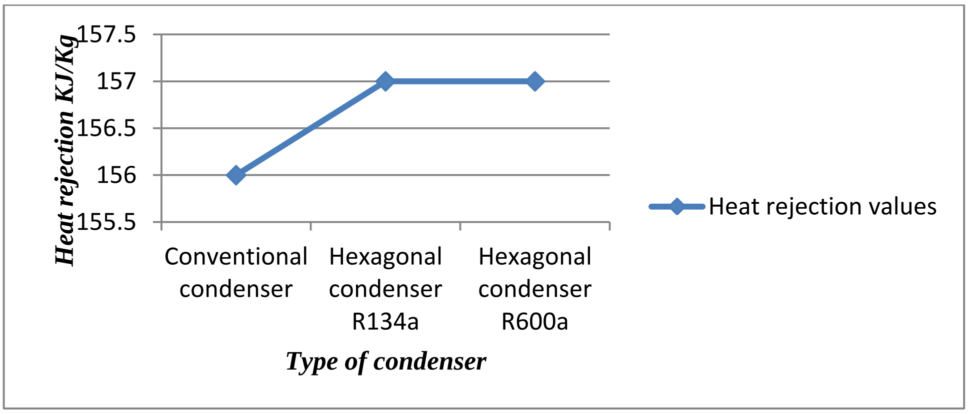

Fig.5.3 Heat rejection in condenser vs. Type of condenser

The effect of heat rejection in condenser is increases, when we change the shape of the condenser coil that give and without unexpected negative effect. Finally the Hexagonal condenser coil obtained moderate amount of heat rejection in condenser. From the results and graph, heat rejection in condenser is increased by 8%.

5.4 Effect of the condenser coil on Net refrigerating effect:

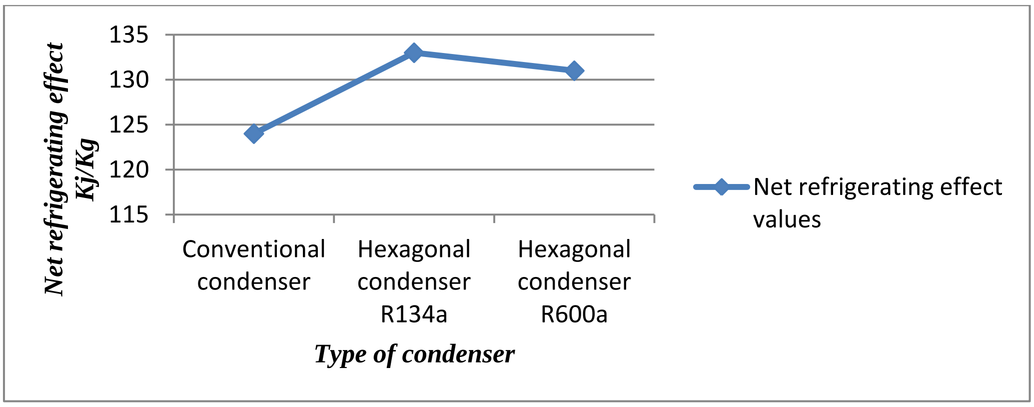

Fig.5.4 Net refrigeration effect vs. Type of condenser

The maximum net refrigeration effect could be obtained by giving minimum load, and the cooling effect also increases. From the results and graph it is observed that, the net refrigerating effect is increases by 16%.

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VI. CONCLUSION

Experimental performance data of a vapour compression refrigeration system with hexagonal shaped condenser coil with refrigerants R134a & R600a has been presented. In addition, the designed coil performance has been compared to that of existing system all at the same cooling capacity and working conditions. The benefits of heat transfer rate while comparing the existing system. While comparison of COP for hexagonal condenser R134a & hexagonal condenser R600a gives nearest values of performance but hexagonal condenser with R134a gives optimum and highest COP. The effects of changing the condenser the following conclusions are drawn from the performance.

- Considering the comparing the COP of the system, it is increased by 17%.
- Considering the comparison of compressor work, it is decreased by 17.13%.
- When conventional condenser coil & hexagonal condenser coil system were compared of heat rejection, it is increased by 8%.
- Considering the comparison of Net refrigerating effect, it is increased by 16%.

Finally it is concluded that Hexagonal shaped condenser coil of diameter 6.4mm and length 9100mm is recommended for VCR system of a domestic refrigerator of 165 lts capacity with R134a as refrigerant.

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