THERMODYNAMIC ANALYSIS OF A DOMESTIC REFRIGERATOR USING R290 AS AN ALTERNATIVE TO R134a

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ABSTRACT

In India, about 80% of the domestic refrigerators use R134a as the refrigerant due to its excellent thermodynamic and thermo physical properties. But, R134a has high Global Warming Potential (GWP) of 1300 times more than CO2. Since, the COP of refrigeration system is based on the energy consumption the proper use of available energy plays an important role. Hence, an attempt was made to evaluate the performance of a domestic refrigerator using R290 refrigerant which is promising alternative refrigerant to R134a. To analyse the domestic refrigerator in the thermodynamic point of view, an experimental setup has been made with domestic refrigerator and the final results showed that the COP of the refrigerator working with R290 refrigerant is higher than COP of the R134a. Finally, it is concluded that the performance of the refrigerator working with R290 refrigerant is better than R134a in terms of exergy efficiency.

KEYWORDS: R290,EXERGY,COP,POWERCONSUMPTION.

1.INTRODUCTION

Nowadays refrigerators are used in most of the houses around the world and also in most of the industrial applications.Refrigerants play the major role in the refrigerators. The refrigerants like air,ammonia,and carbondioxide, sulphur dioxide processing chemical, physical and thermodynamic properties permitting their efficient application and service in the practical design of refrigeration equipment were used in the olden days.Due to high toxicity and low COP these refrigerants were replaced by R12 and R22.But these refrigerants show better COP than the other refrigerants and also it shows higher ozone depletion potential.so, R12 and R22 was replaced by R134a which has zero ozone depletion potential as it has higher global warming potential it is replaced by R290 which has negligible GWP

Murtadha (2008) reported that the R134a used with the capillary tube length of 3m it shows higher power consumption than R22.R134a refrigerant doesn't contain chlorine atoms, thus it has no harm to ozone layer. R134a is safe to use, as it is nonflammable, non-explosive, non-toxic, nonirritant and non-corrosive.

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Compared with R12, R134a has better heat conductivity. This greatly reduces the consumption of refrigerant.

BUKOLA.O.BOLAJI(2007) reported that the decrease in evaporator temperature results in the decrease in COP.Decrease in the evaporator temperature results in the good exergetic efficiency.R134a performs18.2% reduction in COP as compared to R12.MURTADHA(2008) reported that The use of R134a as an alternative refrigerant along with polyolester oil resulted in a 7.5% increase in energy consumption compared to R12.RAHUL UKEY(2012) reported that R12 has exergy of cooling load higher compared to R134a.As R12 reports better performance than R134a but the ozone depletion potential is high in R12 so R134a which is having zero ozone depletion potential is used as an alternative for R12.The investigation with HC mixtures composed of R290 and R600 at different mass ratio in a 240 l capacity domestic refrigerator by replacing the R134a.It was reported that R290/R600 mixture (in the ratio of 60:40, by mass fraction) is the most appropriate alternative to R134a due to its excellent thermodynamics and environmental properties. The refrigerator working with above HC mixture requires less energy conception per day compared to R134a due to its high latent heat. Fatough and EI kafafy (2006) studied the performance of 280 l R134a based domestic refrigerator with liquefied petroleum gas (LPG) composed of R290, R600a and R600(60:20:20 by mass fraction) as an alternative. The results reported that the pull-down time, pressure ratio and power conception of 5m capillary tube length and charge of 60g was reduced by 7.6%,5.5% and 4.3% respectively higher COP. Lower on time ratio and conception of LPG refrigerator by nearly 14.3% and 10.8% respectively, compared to that of R134a [5].

2. EXPERIMENTAL SET UP

A domestic refrigerator was used for conducting an exergy analysis of R134a with the different lengths of the capillary tubes.The capillary tube of 0.36mm diameter and lengths of 3, 3.5, 4, 4.5, 5were used to find the COP for each capillary tube length.The exergy efficiency were also calculated to find the better performance of the refrigerator.The refrigerant was charge a pressure gauge and a thermometer were connected at suction and discharge of the compressor to note down the suction and the discharge pressures and the temperatures.Then it was connected to the condenser and it wasConnected to the drier to filter the dust. It is then sent to the different length of the capillary tubes one by one.The COP was calculated and the power consumption was noted for different length of

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the capillary tubes as per the evaporator temperature upto -10°c.same process is repeated for R290 and the performance is evaluated and compared. The domestic refrigerator experimental setup is shown below.

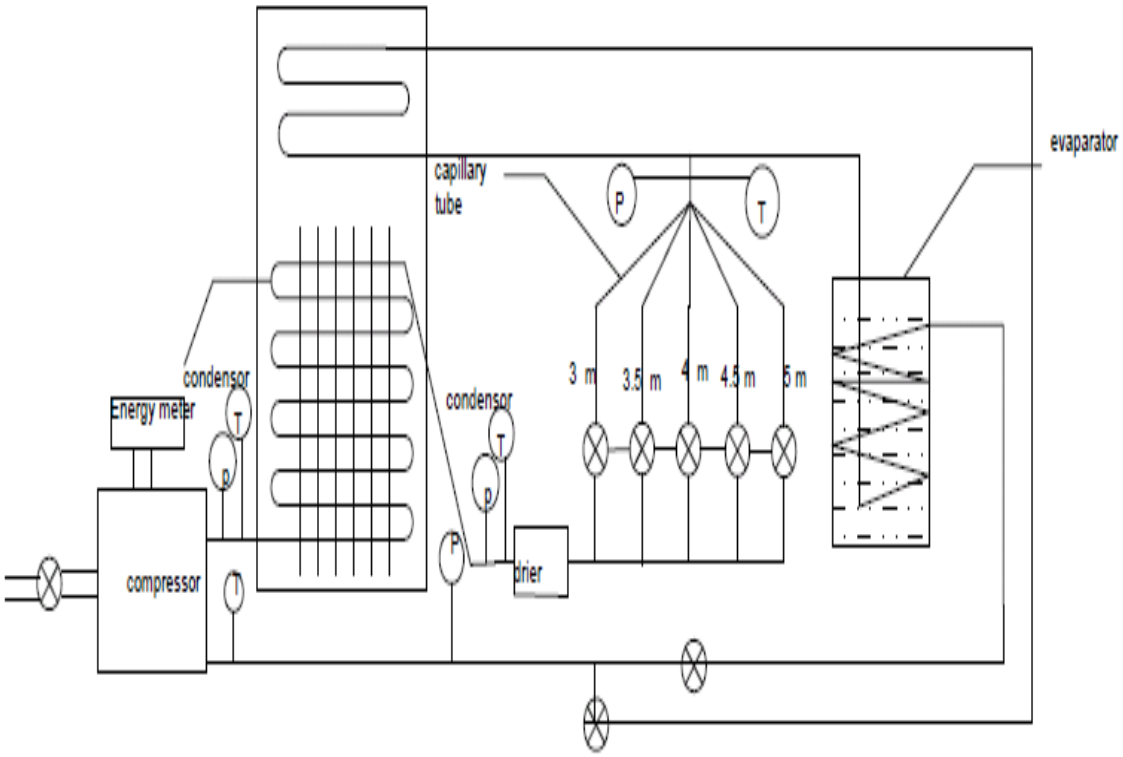

Fig1.Schematic diagram of domestic refrigerator experimental setup

COEFFICIENT OF PERFORMANCE

$$\text{COP}=\frac{h_2 - h_1}{\text{POWER CONSUMPTION}}$$

EXERGY EFFICIENCY

$$\eta_e = \frac{R_e \times (1 - \frac{T_0}{T_e}}{\text{WORK DONE}}$$

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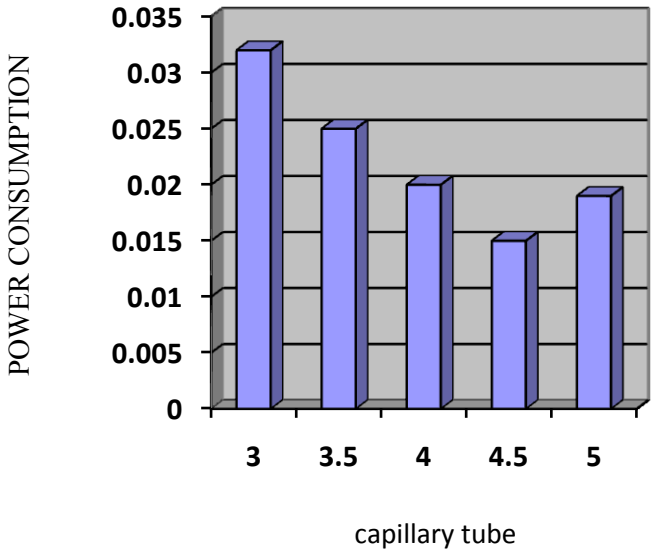
3.RESULTS AND DISCUSSIONS

3.1.POWER CONSUMPTION OF R134a

The power consumption is going to decide the COP of the system. Already the energy resources in India are very limited so we want to reduce the power consumption in all the ways.so In our project we reduce the power consumption in the refrigerator by the optimisation of the capillary tubes usingR134a as the refrigerant which is playing the role of the refrigerants in all of the domestic refrigerators.As a result in our project we found that the power consumption were reduced using the capillary tube length of 3m.as compared to the capillary tube lengths of 3,4,4.5,5.we also obtained relatively comparable results with the capillary tube length of 3m.



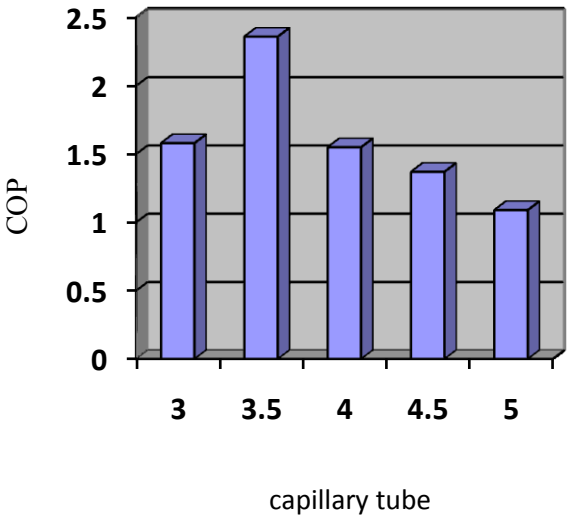


Fig 2.Capillary tube length vs Power consumptionFig 3.Capillary tube length vs COP.

3.2.COEFFECIENT OF PERFORMANCE

In the refrigeration systems the performance is found only by the COP of the system.It is decided by various factors such as the pressure, temperature of the four major componentslike evaporator,condenser and the capillary tube.when the COP of the system is high the system is going to be a better system.The COP of the system is high when the evaporator temperature is high and it gets reduced when the evaporator temperature gets less. Considering the evaporator we done the experiment with the evaporator temperature upto -10˚c.we obtained better COP with the capillary tube length of 3.5m.As the power consumption is also showed experimentally less in the capillary tube length of 3.5m.The COP also relatively equal to the capillary tube length of 3m.

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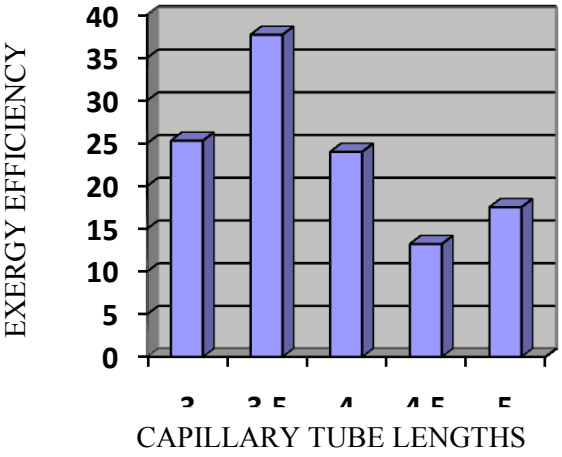
3.3.EXERGY EFFICIENCY

The available energy which is used in the refrigeration system should be better in the four major components evaporator,compressor,condenser,capillary tube.The losses may be due to frictionevaporator design,and due to the ambient temperatures.when the losses gets reduced we can obtain the better COP.In our experiment the exergy efficiency tested for the different capillary tube lengths, respectively with the ambient temperature of 32˚c.we obtained the exergy efficiency of 37.7%.



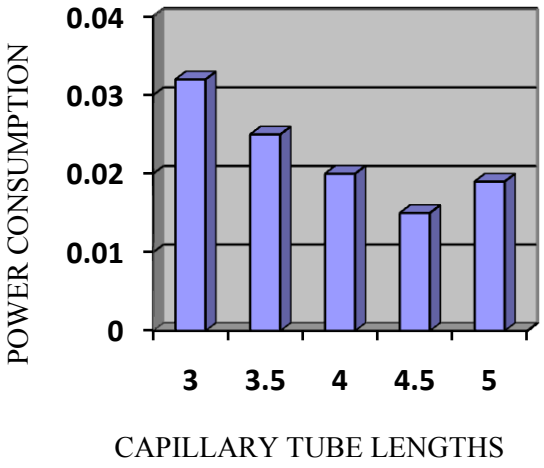


Fig 4.Capillary tube length vs Exergy efficiency. Fig 5.Capillary tube length vs Power consumption

3.4.POWER CONSUMPTION OF R290

As the power consumption in R134a has higher global warming potential it is replaced with R290 . The power consumption was noted with the different capillary tube lengthsThe power consumption is highly reduced in capillary tube length of 4.5m and it got increased in the capillary tube length of size of 3 m.

3.5.COEFFECIENT OF PERFORMANCE

As the power consumption reduces there will be a change in COP.It is observed that the COP is better in the capillary tube length of 4.5 . COP also increased as compared to R134a.It is also shows that the R290 is an eco-friendly refrigerant and can be used in domestic refrigerator without any change in compressor in a domestic refrigerator.

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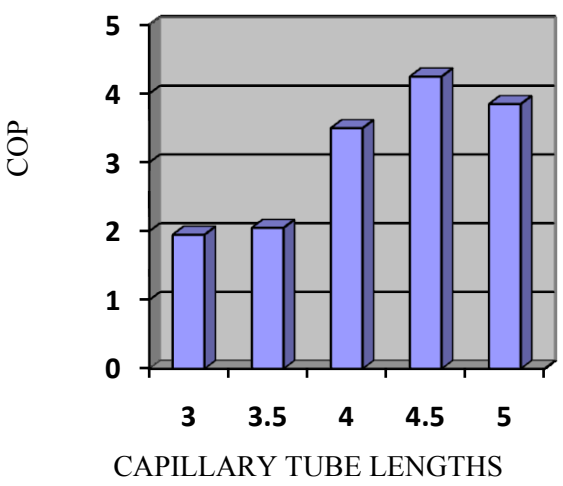

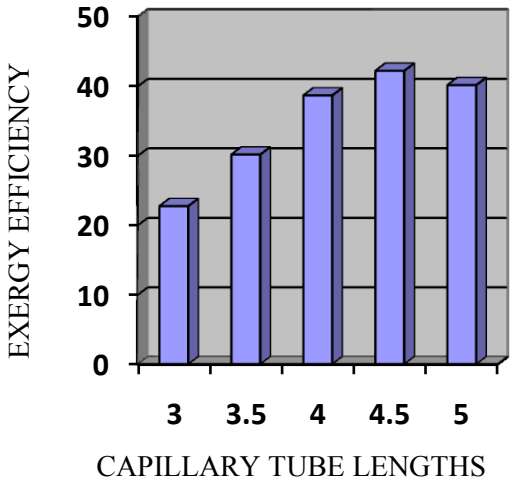

Fig 6.Capillary tube length vs COP.Fig 7.Capillary tube length vs Exergy efficiency.

3.6. EXERGY EFFICIENCY

Exergy efficiency gives the pressure and temperature losses in each capillary tube lengths.it was better in capillary tube length of 4.5m for R290. The losses are mainly due to friction losses and bent losses and refrigerant R290 takes lesser amount of refrigerant than R134a.It also gives better exergy efficiency than R134a.

4. CONCLUSION

The COP and the exergy analysis were done with the optimization of the capillary tubes .The power consumption is mostly reduced for the capillary tube length of 3.5m for R134a.The capillary tube length of 3m shows nearer reduced power consumption compared to3.5m.The exergy analysis also showed that the capillary tube length of 3.5m shows better exergy efficiency .The COP is obtained better in the 3.5m.The power consumption is reducedso the capillary tube length of 3.5 is better preferable for the domestic refrigerators using R134a as refrigerants.As the R134a has higher global warming potential it should be replaced with a eco-friendly refrigerant. It is replaced with R290 which shows less power consumption at the capillary tube length of 4.5m.It also needs lesser amount of refrigerant .R290 also gives better COP and exergy efficiency at the capillary tube length of 4.5m.so it was concluded that the R134a can be replaced with R290 in the domestic refrigerator.

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