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Thermodynamically Evolution of LPG Refrigerator : A Literature Review

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Abstract

This work investigates the result of an experimental study carried out to determine the Coefficient of performance of domestic refrigerator when a propane-butane mixture is liquefied petroleum gas (LPG) which is available and comprises 56.4% butane, 24.4% propane, and 17.2% isobutene. This paper also presented an experimental investigation of COP by the effect of changing capillary tube length, capillary tube inner diameter and capillary coil diameter on the mass flow rate of refrigerant in an adiabatic helical capillary tube. Large amount of electricity supply is not available easily in large part of underdevelopment country like India. It will also prove to be an effective for remote area such as research sites ,mines, & deserts where electricity is generally not available. The LPG is cheaper and possesses an environmental free in nature with no ozone depletion potential (ODP). Also LPG is available as a side product in local refineries. The results of the present work indicate the successful use of this propane-butane mixture as an alternative refrigerant to CFCs and HFCs in domestic refrigerator. It would include Experimental setup of working model and detailed observation of the LPG refrigerator and represents its application in refinery, hotel, chemical industries where requirement of LPG is more.

*Keywords: LPG refrigerator ,domestic refrigerator, eco friendly refrigerants,*Mixed Refrigerant

1. Introduction

The energy crisis persists all across the globe. We think of recovering the energy which is already spent but not being utilized further, to overcome this crisis with no huge investment.The climatic change and global warming demand accessible and affordable cooling systems in the form of refrigerators and air conditioners. Annually billions of dollars are spent in serving this purpose. Hence forth, we suggest NO COST Cooling Systems.

Petroleum gas is stored in liquefied state before its utilization as fuel. The energy spent for pressurizing and liquefying is not recovered afterwards. If it is expanded in an evaporator, it will get vaporized and absorb heat to produce cooling. This property has been used for refrigeration and air conditioning. So that the liquefied form of LPG can be used for cooling and the expanded gas (LPG) can be further used for combustion as a fuel.

The ozone depletion potentials (ODPs) of HFC-134a relative to CFC-11 are very low (<5 · 10_4), the global warming potentials (GWPs) are extremely high (GWP¼1300) For this reason, the production and use of HFC-134a will be terminated in the near future.

The applications of new refrigerant mixtures to replace conventional refrigerants in domestic refrigerators have been studied by a number of researchers. Jung and Radermacher [3] performed a computer simulation of single evaporator domestic refrigerators charged with many pure and mixed refrigerants. The study attempted to find the best potential replacement for CFC- 12. James and Missenden [2] studied the use of propane in domestic refrigerators. Energy consumption, compressor lubrication, costs, availability, environmental factors and safety were the criteria for investigation. The results revealed that propane showed as an attractive alternative to CFC-12. Richardson and Butterworth [2] determined the performance of a vapor compression refrigeration system working with propane and a mixture of propane and isobutane. The obtained performance was higher than that obtained from CFC-12 under the similar experimental conditions. Alsaad and Hammad [10] investigated experimentally the refrigeration capacity, compressor power and coefficient of performance (COP) to determine the performance of a medium size CFC- 12 domestic refrigerator working with a propane/butane mixture. The results indicated the successful application of the mixture of propane and butane for the replacement of CFC-12 in domestic refrigerators. Jung et al. [6] examined the performance of a mixture of propane and isobutane used in refrigerators. A thermodynamic analysis showed that the coefficient of performance of the system was increased up to 2.3% as compared to CFC-12 when the test was run at a mass fraction of propane ranging between 0.2 and 0.6. Tashtoush et al. [4] presented an experimental study on the performance of domestic vapor compression refrigerators with new hydrocarbon/hydrofluorocarbon mixtures as refrigerants for the replacement of CFC-12. The results revealed that a mixture of butane, propane and HFC-134a gave excellent performance. Lee and Su [15] conducted an experimental study on the use of isobutane in a domestic refrigerator. The results showed that the coefficient of performance was comparable with those obtained when CFC-12 and HCFC-22 were used as refrigerants.

LPG consists mainly of propane (R-290) and butane (R-600), and LPG is available as a side product in local refineries. In Cuba for already several decades LPG is used as a drop-in refrigerant. LPG mixtures have composition of a commercial LPG mixture suitable as „drop-in‟ replacement for R-12 was calculated crudely as 64% propane and 36% butane by mass. Liquefied petroleum gas (LPG) of 60% propane and 40% commercial butane has been tested as a drop-in suitable for R 134a in a single evaporator domestic refrigerator with a total volume of 10 ft3.

In march 1989, the Institute of Hygiene in Dortmund Germany needed a new cold storage room. The young idealistic director, Dr Harry Rosin, could not consider using a CFC refrigerant and so tried propane and iso butane.

Greenpeace Australia imported a Foron refrigerator in February 1993 and in December 1993 Email Ltd, Australia‟s largest appliance manufacturer, displayed prototype LPG refrigerators. In 1994, German manufacturer announced one by one their intention of switch to LPG refrigerants.

The US EPA may not approve this either but OZ‟s petition (OZ 1994) is convincing, comprehensive and technically sound especially on safety. Calor released Care 30 in June 1994. Care 30 is a high purity mixture of R-290 and R-600a and is a drop- in replacement for R-12 and R 134a. it has been very successful in vehicle refrigeration and air-conditioning.

2. Construction of the LPG Refrigerator

The LPG refrigerator shown in figure. We have made the one box of the plywood. The plywood sheet size is 12mm for used the LPG refrigerator.

The size of the refrigerator is 255*200*115 mm3.

The evaporator is fitted in the box inside.

Inside the refrigerator, we also put the thermo-coal sheet, because of the cold air cannot the transfer from inside to outside of refrigerator.

The schematically diagram of the LPG refrigeration system is shown in next page. The gas tank is connected by pipes to the capillary tube. The capillary tube is fitted

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with evaporator. The evaporator coiled end is connected to the stove by another gas circulation pipe. When two pressure gauge is put between capillary tube and gas tank, and another is put the end of the evaporator

3 Working of LPG Refrigerator

The basic idea behind LPG refrigeration is to use the evaporation of a LPG to absorb heat. The simple mechanism of the LPG refrigeration working is shown in figure.

LPG is stored under high pressure in LPG cylinder. When the regulator of gas cylinder is opened then high pressure LPG passes in gas pipe. This LPG is going by high pressure gas pipe in capillary tube.
High pressure LPG is converted in low pressure at capillary tube with enthalpy remains constant.

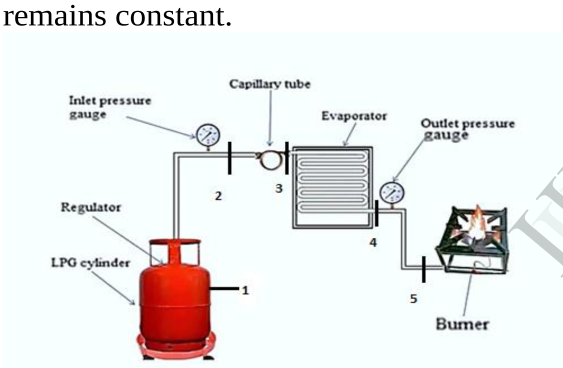

Fig. Working of LPG Refrigerator

After capillary tube, low pressure LPG is passed through evaporator.LPG is converted into low pressure and temperature vapour form and passing through the evaporator which absorbed heat from the chamber. Thus the chamber becomes cooled down. Thus we can achieve cooling effect in refrigerator.
After passing through evaporator low pressure LPG is passed through pipe by burner and we can use low pressureof LPG is burning process.

4. Literature Review

Alternative Refrigerants to R134a system

1. **A.Baskaran & P.Koshy Mathews [5]**A Performance Comparison of Vapour Compression Refrigeration System Using Eco Friendly.Refrigerants of Low Global Warming Potential VCR system with the new R290/R600a refrigerant mixture as a substitute refrigerant for CFC12 and HFC 134a. The refrigerant R290/R600a had a refrigerating capacity 28.6% to 87.2% higher than that of R134a.
2. **A.Baskaran & P.Koshy Mathews [6] ,**A Performance Comparison of Vapour Compression Refrigeration System Using Eco Friendly Refrigerants of Low Global Warming Potential. R600a have a slightly higher performance coefficient(COP) than R134a for the condensation temperature of 50 C^0 and evaporating temperatures ranging between -30 C^0 and10^{0}C.Hence, The coefficient performance (COP) of this mixture was up to 5.7% higher.
3. **M.Mohanraj et. al. [7],** have studied experimentally the drop in substitute for R134a with the environment friendly, energy efficient hydrocarbon (HC) mixture which consists of 45% HC290 and 55% R600a at various mass charges of 50g, 70g and 90g in domestic refrigerator. The experiments were carried out in 165 liters domestic refrigerator using R134a with POE oil as lubricant.The discharge temperatures of HC mixtures are found to be lower than R134a by 13.76%, 6.42% and 3.66% for 50g, 70g and 90g respectively. The power consumption of HC mixture at 50g and 70g are lower by 10.2% and 5.1% respectively and 90g shows higher power consumption by 1.01%. The percentage reduction in pull down time is 18.36%, 21.76% and 28.57% for 50, 70 and 90g mass

charges respectively when compared to R134a. The HC mixture because of its high energy efficiency will also reduce the indirect global warming. In conclusion HC mixture of 70g is found to be an effective alternative to R134a in 165 liters domestic refrigerator.

4. **B.O.Bolaji[8]**, have Experimental study of R152a/R32 to replace R134a in a domestic refrigerator and find out that COP obtained by R152a is 4.7% higher than that of R134a. COP of R32 is 8.5% lower than that of R134a and propane is an attractive and environmentally friendly alternative to CFCs used currently
5. **R.W.James & J.F.Missenden[9],** have use of propane in domestic refrigerators and conclude that he implications of using propane in domestic refrigerators are examined in relation to energy consumption,compressor lubrication, costs, availability, environmental factors and safety propane is an attractive and environmentally friendly alternative to CFCs used currently.
6. **Bilal A. Akash et. al. [10],** has conducted performance tests on the performance of liquefied petroleum gas (LPG) as a possible substitute for R12 in domestic refrigerators.The refrigerator which is initially designed to work with R12 is used to conduct the experiment for LPG(30% propane, 55% n-butane and 15% isobutane). Various mass charges of 50, 80 and 100g of LPG were used during the experimentation.LPG compares very well to R12. The COP was higher for all mass charges at evaporator temperatures lower than −15˚C. Overall, it was found that at 80g charge, LPG had the best results when used in this refrigerator. The condenser was kept at a constant temperature of 47˚C. Cooling capacities were obtained and they were in the order of about three to fourfold higher for LPG than those for R12
7. **M. Fatouh et. al. [11],** investigated substitute for R134a in a single evaporator domestic refrigerator with a total volume of 0.283 m3 with Liquefied petroleum gas (LPG) of 60% propane and 40% commercial butane. The performance of the refrigerator, tests were conducted with different capillary lengths and different charges of R134a and LPG. Experimental results of the refrigerator using LPG of 60g and capillary tube length of 5 m were compared with those using R134a of 100g and capillary tube length of 4 m. Pull-down time, pressure ratio and power consumption of LPG refrigerator were lower than those of R134a by about 7.6%, 5.5% and 4.3%, respectively. COP of LPG refrigerator was 7.6% higher than that of R134a. Lower on-time ratio and energy consumption of LPG refrigerator was lower than 14.3% and 10.8%, respectively, compared to R134a. In conclusion, the proposed LPG is drop in replacement for R134a, to have the better performance, optimization of capillary length and refrigerant charge was needed.
8. **M.A.Hammad et. al. [12],** has experimentally investigated the performance parameters of a domestic refrigerator with four proportions of R290, R600 and R600a are used as possible alternative replacements to the R12.An unmodified R12 domestic refrigerator was charged and tested with each of the four hydrocarbon mixtures that consist of 100% R290, 75%R290/19.1%R600/5.9%R600a, 50%R290/38.3%R600/11.7%R600a and 25%R290/ 57.5%R600/17.5%R600a. The results show that the hydrocarbon mixture with 50%R290/ 38.3%R600/ 11.7%R600a is the most suitable alternative refrigerant which has COP which is 2.7% higher than the R12.
9. **Somchai Wongwises et. al. [13],** has conducted to substitute R134a in a domestic refrigerator with hydrocarbon mixtures of R290, R600 and R600a. A 239 litre capacity refrigerator initially

designed to work with R134a was chosen in the experiment.. The experiments are conducted with the refrigerants under the same no load condition at a surrounding temperature of 25˚C. The results show that 60%R290/40%R600 is the most suitable alternative refrigerant to R134a.

10. **Sanjeev singh punia & Jagdev singh[14] ,** have Experimental investigation on the performance of coiled adiabatic capillary tube with lpg as refrigerant and conclude that There was an increase in mass flow rate by 106%, when the capillary inner diameter was increased from 1.12mm to 1.52mm. When the coil diameter of capillary tube was decreased from 190mm to 70mm, the mass flow rate was decreased by 13%, 7% and 9% for 1.12mm, 1.4mm and 1.52mm inner diameter of capillary tube respectively. 1.40 mm diameter capillary effected the system more as compared to 1.12 mm diameter capillary tube.Mass flow rate increases with increase in capillary inner diameter and coil diameter where as mass flow rate decreases with increase in length. It was observed that the COP of system increases with similar change in geometry of capillary tube
11. **Ju Hyok Kim,Jin Min Cho, Min Soo Kim[15],** have worked on Cooling performance of several CO2/propane mixtures and glide matching with secondary heat transfer fluid, and shows that CO2/propane mixtures is the possibility in keeping the highest pressure of the system below a limit by selecting the composition. The discharge pressure of CO2/propane mixtures is reduced with increasing mole fraction of propane and their reduced values coincide approximately with the circulation concentrations of propanePropane is the refrigerant having a higher refrigerating effect and a much lower vapor density than CO2, adding propane to CO2 improves the system efficiency and reduces the cooling capacity
12. **Gouvernement du Québec 2013 , Propane gas refrigerators - Régie du bâtiment du Québec- [16]** Propane gas refrigerators , installations designed to be supplied with gas requires that any new propane-powered refrigerator be equipped with a gas detector that can shut off propane supply when the burner gives off CO. The flame produced by the burner must be completely blue; if the flame is partly yellow or orange coloured, it is a sign that the burner needs to be cleaned or adjusted.Installing a propane gas refrigerator propane gas refrigerators require a sufficient supply of fresh air to operate safely and efficiently Inadequate ventilation, incomplete combustion or poor evacuation of the combustion products may all cause the building-up of (CO) . the requirements of the Construction Code Verify the tuning of the burner Make sure that the ventilation of the premises is adequate Install a CO detector .
13. **M. Rasti ,M.S. Hatamipour, S.F. Aghamiri, M. Tavakoli[17],** have invesigate on Enhancement of domestic refrigerator's energy efficiency index using a hydrocarbon mixture refrigerant,and sowed that R436A (a mixture of R290 and R600a with a mass ratio of 56/44) in a 238 L single evaporator domestic refrigerator without any modification in refrigeration cycle. The refrigerator's compressor was charged with different amount of R436A.In comparison with R134a, the charge amount of R436A is reduced by 48%; the ON time ratio is reduced by 13%; the energy consumption is reduced by 5.3% in 24 h; the evaporator inlet temperature is reduced by 3.5 C;
The results showed that TEWI of R436A is 11.8% less than R134a.According to our results and known environmental effects,R436A appears to be a suitable replacement for R134a

14. **N.Austin,Dr.P.Senthil Kumar, N.Kanthavelkumaran[18],** have performed on Thermodynamic Optimization of Household Refrigerator Using Propane –Butane as Mixed Refrigerant and find that Pull-down time, pressure ratio and power consumption of mixed refrigerant refrigerator were under those of R134a refrigerator by about 7.6%, 5.5% and 4.3%, respectively. Also, actual COP of mixed refrigerant refrigerator was higher than that of R134a by about 7.6%. Lower on-time ratio and energy consumption of mixed refrigerant refrigerator by nearly 14.3% and 10.8%, respectively, compared to those of R134a refrigerator were achieved.R134a with a charge of 100 g or mixed refrigerant with charge of 80 mg or more satisfy the required freezer air temperature of −12 °C. The lowest electric energy consumption was achieved using mixed refrigerant with heat level is less than -15°C.
15. **Moo-Yeon Lee et. al. [19],** have studied the cooled refrigerator by using the mixture of R600a/R290 with mass fraction of 45:55 as an alternative to R134a. The compressor displacement volume of the alternative system with R600a/R290 (45/55) has modified from that of the original system with R134a to match the refrigeration capacity.The refrigerant charge of the optimized R600a/R290 system was approximately 50% of that of the optimized R134a system. The capillary tube lengths for each evaporator in the optimized R600a/R290 system were 500 mm longer than those in the optimized R134a system. The power consumption of the optimized R134a system was 12.3% higher than that of the optimized R600a/R290 system. The cooling speed of the optimized R600a/R290 (45/55) system at evaporator temperature of −15˚C was improved by 28.8% over that of the optimized R134a system.
16. **A.S. Raut , U.S.Wankhede[20],**have worked on Selection of the Capillary Tubes for Retrofitting in Refrigeration Appliances and try to Use of alternative refrigerants play an important role in forming problems such as global warming and ozone depilationThe coefficient of performance of refrigeration appliances improves in case of retrofitting the capillary tube. It is possible to obtain the effective size (diameter & length) of capillary tube by using of mathematical techniques and by maintaining proper pressure equalization between condenser and evaporator.The coefficient of performance of refrigeration appliances improves in case of retrofitting the capillary tube.

5. Conclusion

Finding from literature we conclude that:

- Propane is an attractive and environmentally friendly alternative to CFCs used currently.
- Mass flow rate increases with increase in capillary inner diameter and coil diameter where as mass flow rate decreases with increase in length. It was observed that the COP of system increases with similar change in geometry of capillary tube.
- The coefficient of performance of refrigeration appliances improves in case of retrofitting the capillary tube.
- Cooling capacities were obtained order of about three- to fourfold higher for LPG than those for R-12.
- COP of LPG refrigerator was higher than that of R134a by about 7.6%. LPG seems to be an appropriate long-term candidate to replace R134a in the existing refrigerator,

except capillary tube length and initial charge.

- High COP values were obtained No operation problems have been encountered compressor.The use of LPG as a replacement refrigerant can contribute to the solution of (ODP) problem and global warming potential.
- It seems that propane/butane 60%/40% is the most appropriate alternative refrigerant to HFC-134a.

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