Determination of Refrigerating Effect using LPG as a Refrigerant using Different Capillary Tubes

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Abstract— The project analyses the result of an experimental study carried out to determine the performance characteristics of a simple refrigerator when domestic liquefied petroleum gas (LPG) which is locally available which comprises of 24.5% propane, 56.5% butane and 17.3% isobutene which is varied based on the company is used as a refrigerant. The LPG is cheap and possesses an eco-friendly nature with zero Ozone Depletion Potential (ODP) and zero Global Warming Potential (GWP). It is used worldwide mostly for cooking purposes. The refrigerator used in our experimental setup is designed to work on LPG. The performance characteristics analysed is the refrigeration effect and the evaporator temperature in certain time. The refrigerator worked fair enough when LPG was used as a refrigerant instead of traditional R134a. The evaporator coil temperature reached 8°C with an ambient temperature of 33°C. Also the experiment is carried out in atmospheric conditions, so that we can calculate the best value of cooling effect with the suitable operating condition of regulating valve and capillary tube of the system.
Key words: LPG, Refrigerant, Capillary Tubes, Eco-friendly

I. Introduction

In our country, HFC 134a is used as a refrigerant for domestic refrigerators, due to its excellent thermodynamic and thermo-physical properties. But, HFC 134a has a high global warming potential (GWP) of 1300. There is a need of discovering refrigerants which can act as alternative to the conventional refrigerants. CFC's are generally destroyed by UV radiations in the stratosphere; the chlorine(Cl) released in the high stratosphere altitude catalyses the decomposition of ozone to oxygen; and UV radiations penetrate to lower altitudes. The amount of energy spent for pressurising the gas in LPG is not utilised. We can use this pressurised LPG and make it to expand in an evaporator or expansion device, it will be vaporized and will absorb heat in order to produce cooling effect. The expanded gas can further be used as fuel for combustion. Thus, we can utilise the pressure energy of high pressure LPG.

This project studies the result of an experimental study carried out using a setup which uses liquefied petroleum gas (LPG) which is locally available which comprises of 24.5% Propane, 56.5% Butane and 17.3% isobutene which is varied based on manufacturer is used as a refrigerant. The LPG is cheap and has an environmentally friendly nature with zero Ozone Depletion Potential (ODP) and zero Global Warming Potential (GWP). It is used all over the world for cooking purposes. In our setup, we are going to study the effect of change in diameter of capillary tubes on refrigeration effect. We are also going to see the effect of change in geometry of capillary tubes. For this purpose, we will be using two helical and two spiral capillary tubes of two different diameters respectively.

II. Literature Survey

Baskaran et. al. 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 forCFC12 and HFC 134a. The refrigerant R290/R600a had a refrigerating capacity28.6% to 87.2% higher than that of R134a. R600a have a slightly higher performance coefficient(COP) than R134a for the condensation temperature of 50 C° and evaporating temperatures ranging between -30 C° and O°C. Hence, The coefficient performance (COP) of this mixture was up to 5.7% higher consumption, compressor lubrication, costs, availability, environmental factors and safety Propane is an attractive and environmentally friendly alternative to CFCs used currently.[2]

Bilal A. et. al. conducted performance tests on the performance of liquefied petroleum gas (LPG) as a possible substitute for R12in domestic refrigerators. The refrigerator which is initially design to work with R12 is used to conduct the experiment for LPG (30% Propane, 55%N-Butane and 15% isobutene). Various mass charges of 50, 80 and 1OOg 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. [6]

M. Mohanraj et. al. have studied experimentally the drop in substitute forR134a with the environment friendly, energy efficient hydrocarbon (HC) mixture which consists of 45% HC290and 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 power consumption of HC mixture at 50g and 70g are lower by 10.2% and 5.1% respectively and90g shows higher power consumption by 1.01%. The percentage reduction in pull down time is 18.36%, 21.76% and28.57% 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. [7]

B.O.Bolaji have experimentally studied 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. [3]

R. W. James et. al. used Propane in domestic refrigerators and concluded that the implications of using Propane in domestic refrigerators are examined in relation to energy. [8]

M. Fatouh et. al. 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 1OOg 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 dropping in replacement for R134a, to have the better performance, optimization of capillary length and refrigerant charge was needed. [10]

Sanjeev Singh Punia et. al. 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 byl3%, 7% and 9% for 1.12mm, 1.4mm and 1.52mm inner diameter of capillary Tube respectively. 1.40 mm diameter capillary affected 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. [9]

Somchai Wongwises et. al. conducted to substitute R134a in a domestic refrigerator with hydrocarbon Mixtures of R290,R600 and R600a. A239 liter capacity refrigerator initially designed to work with R134a was chosen in the experiment. The experiments were conducted with the refrigerants under the same no load condition at a surrounding temperature of 25°C. The results showed that 60% R290/40% R600 is the most suitable alternative refrigerant to R134a. [11]

III. Problem Statement

The discovery that chlorofluorocarbons (CFCs), widely used as refrigerants, are causing ozone depletion, and the increasing energy efficiency awareness brought about in part by the Green House Effect (caused mainly by the burning of fossil fuels) necessitates a significantly different approach to the design of a refrigerator. In our country, HFC 134a is used as a refrigerant for domestic refrigerators, due to its excellent thermodynamic and thermo-physical properties. But, HFC 134a has a high global warming potential (GWP) of 1300. There is a need of discovering refrigerants which can act as alternative to the conventional refrigerants. CFC's are principally destroyed by ultraviolet radiations in the stratosphere; the chlorine released in the high stratosphere catalyses the decomposition of ozone to oxygen; and ultraviolet radiations penetrate to lower altitudes. Credible calculations of the magnitude of the effect (Hoffman 1987) and his team predicted 3% global ozone depletions for constant CFC emissions of 700 thousand tonnes/year after a hundred years. High GWP and ODP are not desirable for a refrigerant. Hence, there was a need to use a refrigerant with lowest GWP and ODP. So, LPG is introduced as a refrigerant in our project.

IV. Methodology

The basic idea behind LPG refrigeration is to use the evaporation of LPG to absorb heat. LPG is stored in LPG cylinder under high pressure. When the gas valve of regulators is opened, the high pressure LPG passes in the LPG pipe. This LPG passes through high pressure gas pipe in the capillary tube. When LPG is passed through capillary tube, sudden pressure drop is witnessed due to the unusual change in diameter . After passing through capillary tube, low pressure LPG passes through evaporator. LPG is converted into low pressure and temperature vapour form and passing through the evaporator which absorbs heat from the chamber. Thus the chamber cools down. Thus we can achieve cooling effect in the refrigerator. After passing through the evaporator coil, low pressure LPG is passed through the gas pipe to burner. After that, we can use the low pressure of LPG for burning process.

V. Construction of LPG Refrigerator

The refrigeration box or cabinet measurements are 0.61 m * 0.6 m * 0.91 m when measured from outside. The total area which is refrigerated in our setup is 0.566 m * 0.512 m * 0.77 m respectively. The cooling will take place in this area only. The refrigeration box is supported on a frame which is approximately 0.91m in height and its base forms a square of side 0.61m. For other mountings such as pressure gauge, capillary tube mounting, accumulator etc. provision is made on the frame itself. The frame is constructed using hollow steel square rods by welding.

The refrigeration box is constructed using G.I sheets of 22 gauge and 24 gauge for inner and outer surfaces respectively. Between these two G.I sheets, thermocol of width 2 inches is kept for insulation purpose. The G.I sheets are bent according to our requirement and joint wherever needed using rivets. The box is constructed such that the thermocol is covered with G.I sheet from all sides. Door is mounted with the help of hinges. The construction of door is also done using G.I sheets and thermocol. To keep proper contact between the door surface and box surface, insulating rubber strip is attached between the two. The evaporator coil is fitted in the inner upper surface of the refrigeration box.

High pressure pipe is used to connect LPG gas cylinder to the copper tubing. The copper tubing used here is of 0.33inch diameter. The copper tubing is further connected to a pressure gauge. This pressure gauge is used to measure inlet pressure. In our setup, we have used pressure gauge with valve which can be used for measuring the inlet pressure as well as controlling the pressure going forward. Further, the copper tubing is connected to respective hand valves with the help of copper 'T's. Each valve is connected to a separate capillary tube via a filter-drier. In our setup we have used four different capillary tubes. Thus we will be using four hand valves and four filter-driers respectively.

All the four capillary tubes are connected to the evaporator which is fitted in the inner upper surface of the refrigeration box. By using hand valves we can control the flow of refrigerant and make it to flow through one capillary tube only. A bigger copper tubing of about 0.375inches is used to connect the four capillary tubes and the evaporator in our setup. The exit of the evaporator coil is connected using copper tubing and is taken out of the refrigeration box and is connected to the accumulator. Further it is connected to the outlet pressure gauge in order to measure the outlet pressure. All the connections are made using special nuts and bolts available in the market. Copper tubing connections are made using brazing process. Mostly, brazing is carried out in most of the connections. Leak test is carried out using foam method. Again a domestic gas pipe is used at the outlet of the pressure gauge which is attached to a burner. Thus, the gas can be utilised and can be used for daily needs like cooking, boiling etc.

Fig. 1: Experimental Setup (Back)

Fig. 2: Experimental Setup (Front)

VI. EXPERIMENTAL ANALYSIS

Operational Parameters,
Dimensions of cabinet (Refrigeration box):-
Length = 0.566 m,
Breadth = 0.512 m,
Height = 0.7 m
Therefore, Volume of cabinet = Length * Breadth * Height (m^3)

$$V = 0.566 * 0.512 * 0.77$$
$$V = 0.22314\ m^3$$

To find the mass of air (m)

$$PV = m*R*T$$
$$m = \frac{PV}{RT}$$
$$RE = m*C_{pa}*\frac{\Delta T}{t}$$

Table 1 and 2 shows the performance characteristics of LPG refrigerator for helical capillary tube of inner diameter 1 mm and length 2 m.

Table 1 and 2. Observation Table for Helical Capillary Tube of dia. 1 mm

Time (sec)	P_1 (psi)	P_2 (psi)	Cabinet air temp T (K)	C_{pa} (J/kgK)
0	46	8	303.6	1006.5
600	46	10	298.1	1006
1200	46	9	295.2	1005.9
1800	46	9	293.6	1005.9
2400	46	9	292.3	1005.9
3000	46	9	291.6	1005.9
3600	46	9	291.3	1005.9

Table 1. Cabinet air temperature and specific heat of air for helical capillary tube of dia. 1 mm.

Time (sec)	ΔT (K)	m (kg)	RE (TR)	R.E (Watt)
0	0	0.259484		
600	5.5	0.264271	$6.96*10^{-4}$	2.4377495
1200	8.4	0.266868	$5.37*10^{-4}$	1.879655
1800	10	0.268322	$4.29*10^{-4}$	1.4997702
2400	11.3	0.269515	$3.65*10^{-4}$	1.2767082
3000	12	0.270162	$3.11*10^{-4}$	1.0871327
3600	12.3	0.27044	$2.66*10^{-4}$	0.9295489

Table 2. RE for helical capillary tube of dia. 1 mm

Table 3 and 4 shows the performance characteristics of LPG refrigerator for spiral capillary tube of inner diameter 1 mm and length 2 m.

Table 3 and 4. Observation Table for Spiral Capillary Tube of dia. 1 mm

Time (sec)	P_1 (psi)	P_2 (psi)	Cabinet air temp T (K)	C_{pa} (J/kgK)
0	46	12	303.8	1006.4
600	46	14	297.8	1006.3
1200	46	12	292.1	1006.1
1800	46	12	288.9	1006
2400	46	9	288.4	1005.9
3000	46	12	288.2	1005.9
3600	46	12	287.8	1005.9

Table 3: Cabinet air temperature and specific heat of air for spiral capillary tube of dia. 1 mm.

Time (sec)	ΔT (K)	m (kg)	RE (TR)	R.E (Watt)
0	0	0.259313		
600	6	0.264538	$7.61*10^{-4}$	2.6620421
1200	11.7	0.2697	$7.56*10^{-4}$	2.6456132
1800	14.9	0.272687	$6.49*10^{-4}$	2.2707867
2400	15.4	0.27316	$5.04*10^{-4}$	1.7631171
3000	15.6	0.273349	$4.09*10^{-4}$	1.4298033
3600	16	0.273729	$3.50*10^{-4}$	1.2237526

Table 4: RE for spiral capillary tube of dia. 1 mm

Table 5 and 6 shows the performance characteristics of LPG refrigerator for helical capillary tube of inner diameter 1.2 mm and length 2 m.

Table 5 and 6. Observation Table for Helical Capillary Tube of dia. 1.2 mm

Time (sec)	P_1 (psi)	P_2 (psi)	Cabinet air temp T (K)	C_{pa} (J/kgK)
0	46	26	304.3	1006.5
600	46	22	298.1	1006.2
1200	46	22	295.2	1006
1800	46	20	291.3	1005.9
2400	46	20	290.6	1005.9
3000	46	20	289.4	1005.8
3600	46	20	288	1005.7

Table 5: Cabinet air temperature and specific heat of air for helical capillary tube of dia. 1.2 mm.

Time (sec)	ΔT (K)	m (kg)	RE (TR)	R.E (Watt)
0	0	0.258887		
600	6.2	0.264271	$7.85*10^{-4}$	2.7480085
1200	9.1	0.266868	$5.82*10^{-4}$	2.0362929
1800	13	0.27044	$5.61*10^{-4}$	1.9649001
2400	13.7	0.271092	$4.45*10^{-4}$	1.5567678
3000	14.9	0.272216	$3.89*10^{-4}$	1.3599828
3600	16.3	0.273539	$3.56*10^{-4}$	1.2458322

Table 6. RE for helical capillary tube of dia. 1.2 mm

Table 7 and 8 shows the performance characteristics of LPG refrigerator for spiral capillary tube of inner diameter 1.2 mm and length 2 m.

Table 7 and 8. Observation Table for Spiral Capillary Tube of dia. 1.2 mm

Time (sec)	P_1 (psi)	P_2 (psi)	Cabinet air temp T (K)	C_{pa} (J/kgK)
0	46	25	304.9	1006.5
600	46	23	298.9	1006.1
1200	46	23	294.5	1005.9
1800	46	23	291.7	1005.8
2400	46	23	289.3	1005.8
3000	46	23	287.6	1005.8
3600	46	23	285.4	1005.8

Table 7: Cabinet air temperature and specific heat of air for spiral capillary tube of dia. 1.2 mm.

Time (sec)	ΔT (K)	m (kg)	RE (TR)	R.E (Watt)
0	0	0.258378		
600	6	0.263564	$7.5*10^{-4}$	2.6522453
1200	10.4	0.267502	$6.66*10^{-4}$	2.3324915
1800	13.2	0.27007	$5.69*10^{-4}$	1.9925915
2400	15.6	0.27231	$5.09*10^{-4}$	1.7806355
3000	17.3	0.27392	$4.54*10^{-4}$	1.5890812
3600	19.5	0.276031	$4.30*10^{-4}$	1.5041400

Table 8: RE for spiral capillary tube of dia. 1.2 mm

VII. Result Analysis

According to the calculations done after conducting tests on all four different capillary tubes for 60 minutes, following results are achieved. Helical capillary tube of diameter 1 mm gave refrigerating effect of 0.929 Watt. Spiral capillary tube of diameter 1 mm gave refrigerating effect of 1.2237 Watt. Helical capillary tube of diameter 1.2 mm gave refrigerating effect of 1.2458 Watt. Spiral capillary tube of diameter 1.2 mm gave refrigerating effect of 1.5041 Watt. Thus, it can be seen that the spiral capillary tube of diameter 1.2 mm has the best refrigerating effect among the four capillary tubes we have used in our setup. Whereas the helical capillary tube of diameter 1 mm had the least refrigerating effect among the four capillary tubes we have used in our setup.

VIII. Conclusion

The aim of the LPG refrigerator is to use LPG as a refrigerant and to recover waste heat to produce refrigerating effect. With the help of capillary tube we are going to produce a pressure drop and obtain a cooling effect. So we will calculate the refrigerating effect with the help of changes in properties like pressure of LPG before and after using high pressure regulator. We will be using helical and spiral capillary tubes of different diameters and thereby will calculate the refrigerating effect. We will also compare the refrigerating effects obtained by helical and spiral capillary tubes of different diameters.

IX. FUTURE SCOPE

The basic objective was to study LPG refrigeration system. We are substituting the compressor and condenser by a LPG cylinder. The high pressure energy of LPG is utilised using capillary tube and evaporator coil. A new product in the field of refrigeration is introduced and is expected to give out positive result with this normal product. The main aim is to focus on restaurant and community program hall, mid-day meal of school so to preserve food products like vegetables, milk etc. Also at small snack stores by increasing the probability of refrigerator by reducing its weight, removing compressor totally as well as maximum cost reduction due to no cost of refrigeration.

1) The mine, desert and research areas and countries where lack of electricity this product might be beneficial.
2) This product can also be used in LPG car air conditioning
3) In restaurants, where LPG is continuously used so that the high pressure of LPG can be utilized to obtain cooling effect.
4) It can also hold good application in rural areas who have less or no access to electricity and refrigerators.

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