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Thermodynamically Evolution of LPG Refrigerator in Mobile Refrigerator

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ABSTRACT

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. This work investigates the result of an experimental study carried out to determine the 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. An experimental investigation of Performance is carried out 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 under development 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 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: Refrigerator, domestic refrigerator, ecofriendly refrigerants, Mixed Refrigerant

I. 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/hydro fluorocarbon 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.

Conceptual Development of LPG Refrigerator

From the literature reviews and theoretical studies, it is clear that many operational and physical factors contribute to the Refrigerator performance of LPG. Since the targeted outcome of their research is a miniaturized LPG refrigerator, in which evaporator and capillary tube are the main component, an adequate physical design of ad sorter in small volume and light weight are priority .Operating parameters are considered during the design procedure but will be optimized later during experimental testing.

The LPG Refrigerator

The schematic diagram of LPG refrigeration cycle is shown below.

Figure1 : LPG Refrigerator Setup

LPG Gas Cylinder: LPG gas pressure is approximate 80-100 psi.LPG flows through high pressure pipe and reaches to the capillary tube from the LPG gas cylinder.

Capillary Tube: As the capillary tube, capillary tube drops the pressure up to less than 1 psi.

Evaporator: LPG is converted into the vapour from with low pressure in the evaporator. After flowing through the evaporator low pressure and temperature LPG vapour extract heat from the chamber system.

Gas Burner: Low pressure LPG gas goes into the burner to burns after performing the cooling effect.

II. Capillary Tube and Its Sizing

Now there are two approaches to design.
i. Isenthalpic expansion, as shown by link k-a.

ii. Adiabatic or Fanno-line expansion, as shown by line k-b.

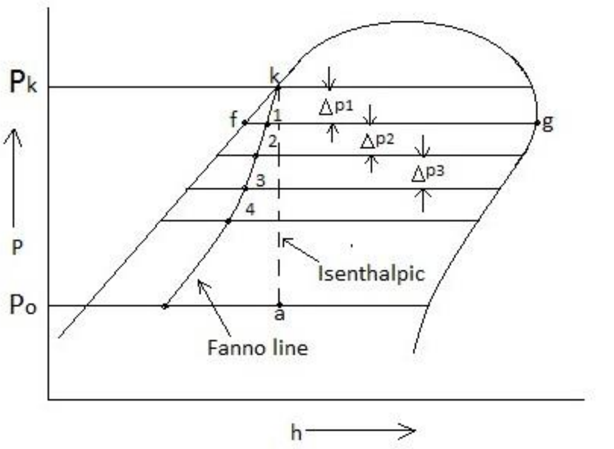

Figure 2. Incremental pressure drops in a capillary tube

The steps of calculation to be followed are:

1. Determine the quality at the end of the decrement assuming isenthalpic flow. Then at point 1 at pressure p1

$$x_1 = \frac{h_k - h_{f_1}}{h_{fg1}}$$

2. Determine the specific volume

$$v_1 = \quad v_{f_1} + x_1(\text{ı}$$

3. Calculate the velocities from the continuity equation at both the ends of the element

$$u_k = \frac{\dot{m} v_k}{A} \;,\; u_1 = \frac{\dot{m} v_1}{A}$$

Or $$\frac{u}{v} = \frac{\dot{m}}{A} = G$$

Where G is mass velocity.

4. For Fanno-line flow, an iteration procedure is necessary. This is done by applying the correction to enthalpy since h1≠ hk. Thus

$$h_1 = h_k - \frac{u_1^2}{2}$$

5. Determine the pressure drop due to the acceleration, pA, from the momentum equation

Adp = mdu

Hence,

$$\Delta p_A = \frac{\dot{m}}{A}\,(u_k - u_1) = G(u_k\text{- } u_1)$$

6. Determine the pressure drop due to the friction, pF, from

$$\Delta p_F = \Delta p - \Delta p_A$$

The friction factor is a function of Reynolds number which in turn is expressed as

$$Re = \text{Du}\text{þ}/\mu = \text{DG}/\mu = \text{Z}/\ \mu$$

Where , **Z = DG**

Niaz and Davis[5] have proposed the following correlation for evaluating the friction factor:

$$f = \frac{0.324}{Re^{0.25}}$$

7. Equate the required frictional pressure drop

$$\Delta p_F = \frac{\rho f \Delta L u^2}{2D}$$

$$\Delta p_F = \frac{G}{2D} f u \Delta L = Y\ f u\ \Delta L$$

Where,

$$Y = \frac{G}{2D}$$

- By the use of **MatLab R2007B** software , optimization of capillary tube give the following data.

Table.1 Capillary tube sizing

Sr No	Capillary inner diam.(m)	Capillary tube Length(m)	Mass flow rate (Kg/hr)
1	0.0007	3.5	0.20
2	0.00078	2.83	0.46
3	0.00112	2.77	0.69

III. Experimental Analysis

To evaluate thermodynamic of LPG refrigerator there is to validate through experimentation. Whole experimentation is divide into three for collecting data for evaporator temperature & water temperature .from repeatability of reading and comparison study of all three design. This analysis could able to propose best design for capillary tube.

Here, experimental studies of LPG refrigerator are carried out and the design alternatives are varied in following design.

1. Design:-1(Capillary inner diameter 0.7mm ,capillary length 3.5m and coil diameter varied by 70mm)
2. **2.** Design:-2(Capillary inner diameter 0.78mm ,capillary length 2.83m and coil diameter varied by 70 mm**)**
3. **3.** Design:-3(Capillary inner diameter 1.12mm ,capillary length 2.77m and coil diameter varied by 70 mm)

Operational Parameters

Size of Refrigerator:-16. x 7 x 9.5 inches^3 Initial temperature of water at the time of experiment:- 36 ^{0}C
Initial temperature of evaporator at :- 34.5^{0}C

IV. Observation Table

1. Design:-1(Performance characteristic of LPG for Capillary tube inner diam.-0.7mm, length- 3.5m, coil diam.-70mm)

Long capillary designed coiled because it significantly higher the pressure drop and allow produces low temperature in evaporator. In this design the capillary diameter are considered with same inner diameter and length and evaporator and water temperature is evaluated.

The experimental 5 results for design 1 with 70mm coil diameter shows that desirable temperature drops achieved.

2. Design:-2(Performance characteristic of LPG for Capillary tube inner diam.-0.78mm, length- 2.83m, coil diam.-70mm)

Medium capillary designed coiled because it significantly higher the pressure drop and allow produces low temperature in evaporator. In this design the capillary diameter are considered with same inner diameter and length and evaporator and water temperature is evaluated.

The experimental 5 results for design 2 with 70mm coil diameter shows that desirable temperature drops achieved.

Table.2 Evaporator & water temperature for coil diam.-70mm

Sr No	Inlet Pressure (psi)	Outlet Pressure (psi)	Time (min)	Evao.temp (c◦)	Water temp.(c◦)
1	60	25	10	31	33.1
2	60	22	20	25	32.3
3	60	18	30	23	28.4
4	60	16	40	20	24.2
5	60	14	50	18	22.1

Table 3. Evaporator & water Temperature for coil diam.-70mm

Sr No	Inlet Pressure (psi)	Outlet Pressure (psi)	Time (min)	Evapo. temp. °C	Water temp. °C
1	60	23	10	30	32.2
2	60	21	20	24.2	31.5
3	60	19	30	22.1	27.5
4	60	15	40	19	23.1
5	60	13	50	15	21.4

3. Design:-3(Performance characteristic of LPG for Capillary tube inner diam.-1.12mm, length- 2..77m, coil diam.-70mm)

Low capillary designed coiled because it significantly higher the pressure drop and allow produces low temperature in evaporator. In this design the capillary diameter are considered with same inner diameter and length and evaporator and water temperature is evaluated

The experimental 5 results for design 3 with 70mm coil diameter shows that desirable temperature drop achieved.

Table 4. Evaporator & water Temperature for coil diam.-70mm

Sr No	Inlet Pressure (psi)	Outlet Pressure (psi)	Time (min)	Evapo. Temp. ℃	Water temp. ℃
1	60	24	10	31.2	33.8
2	60	23	20	25.1	32.7
3	60	19	30	24.2	29.4
4	60	17	40	22.1	26.2
5	60	15	50	19.3	23.4

Result Analysis

Fig.3 shows the water temperature variation between different capillary tube with 0.7 ,0.78 ,1.12 mm coil inner diameter, same outer coil diameter and 3.5, 2.83, 2.77m capillary length respectively. It's concluding that the maximum water temperature will decrease with 0.78mm inner coil diameter capillary tube with 2.83m length.

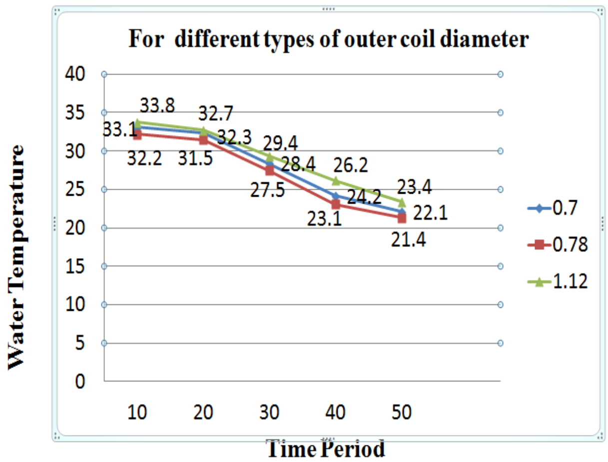

Figure 3. Comparison of Water temp. vs Time period for different capillary tube

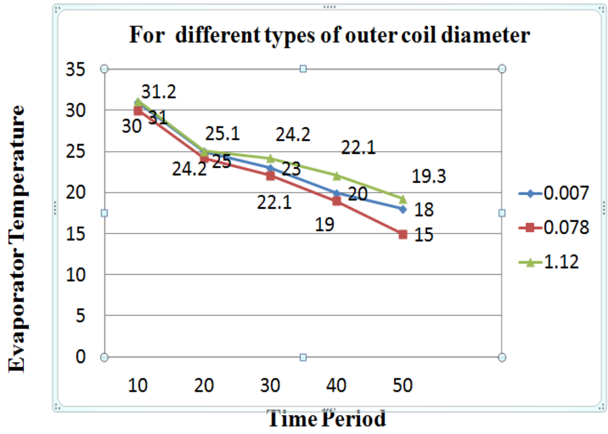

Figure 4. Comparison of Evaporator temp. vs Time period for different capillary tube

Fig.4 shows the Evaporator temperature variation between different capillary tube with 0.7 ,0.78 ,1.12 mm coil inner diameter, same outer coil diameter and 3.5, 2.83, 2.77m capillary length respectively. It's conclude that the maximum evaporator temperature will decrease with 0.78mm inner coil diameter capillary tube with 2.83m length .

V. Result Table

Result table shows the mass flow rate as well as temperature difference obtained after the each experiment completed. Result of temperature difference obtained after 150 minutes of observation.

The desired pressure drop with 15°C of temperature drop and above is achieved in all three design configuration. Above experimental studies elaborate all designs:

Here, we try to achieve 15°C temperature drop and 48 Psi pressure drop. At the end of all experiments with different capillary tube inner diameter, outer coil diameter with different length, found that capillary tube with 0.78mm inner diameter,70mm coil diameter with 2.83m length gives most efficient performance than other capillary tube with different parameters.

Table.5 Evaporator & water Temperature for coil diam.-70mm

Table.11 Result Table

Capillary coil diameter (mm)	Capillary tube length (m)	Capillary inner diameter (mm)	Mass flow rate (Kg/hr)	Water Temp. difference (Δt)(°C)
70	3.5	0.7	0.20	13.9
	2.83	0.78	0.46	14.6
	2.77	1.12	0.69	12.6

Effect of Capillary length on the Performance of the System

The Performance of system is plotted through temperature difference against different diameters of outer coil .The lowest temperature achieved at the end of each performance of the system against different diameter of capillary tube is plotted with reference at 36 ℃ ambient temperature. Figure.10 shows the plot between temperature difference and coil inner diameter of 0.7, 0.78 , 1.12mm with 3.5, 2.83, 2.77 m length of capillary tube respectively . When geometry of capillary tube was constant at 70mm, The Performance of system increased from 1.12 mm to 0.78 mm of capillary tube inner diameter with 2.77 m to 2.83 m of capillary tube length respectively.

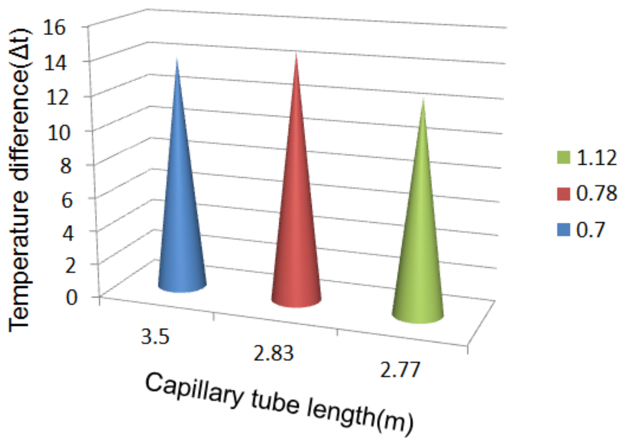

Figure 10. Comparison of Temperature achieved vs Capillary length for different capillary tube

VI. CONCLUSION

At the end of all experiments with retrofitting different kind of capillary tube , I would like to conclude that refrigerating effect is produced by using LPG as a refrigerant in "NON ELECTRIC REFRIGERATOR".

- By change the design of capillary tube, I conclude that, the maintaining the regulating valve of LPG at 60 Psi ,the achievement of chamber temperature decrease from 34.5 ºC to 15ºC in a 150 minute. With the Design 2 having capillary tube inner diameter 0.78mm ,coil diameter 70mm and capillary length 2.83m.
- Having also put the water in a bowl inside the evaporator. The initial temperature of water is 36 ºC. From experimental result, we found that, for the same time period can achieve the temperature of water is 21 ºC.
- I also conclude that the maximum pressure of gas cylinder is reduces by the capillary tube is less than of 40 psi. The most suitable throttling device used as capillary tube is in LPG refrigeration system.
- After completion of experimentation work using all three types of design, I would like to conclude that, Capillary tube with inner diameter 0.78mm , length of 2.83m and outer coil diameter about 70mm gives the most efficient refrigerating effect than any other of two design. And it's look more suitable device for the NON ELECTRIC LPG REFRIGERATOR.
- This system dose not require an external energy sources to operate the system and no moving parts used so maintenance is minor.
- I also conclude that, I try the burnt to the exhaust LPG, the pressure of exhaust gas is maintain less than 1 psi using regulator , the stimulate flame produce by the burner.

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