

LPG REFRIGERATION SYSTEM WITH ZERO OPERATING COST

**Mr.Abhishek Prasad Shelke, Mr.Vikas Sheshrao Sonpir,
Mr.Pradip Ramchandra Jadhav, Mr.Prashant Suresh Thorat
Guide Prof.A.M.Salwe**

Department of Mechanical Engineering
Bhivrabai Sawant Institute of Technology and Research, Wagholi, Pune

Abstract: *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 locally available and comprises 24.4% propane, 56.4% butane and 17.2% isobutene which is very from company to company. The LPG is cheaper and possesses an environmental friendly nature with no ozone depletion potential (ODP). It is used in world for cooking purposes. The various methods of refrigeration on the basis of standard refrigerant discussed. He refrigerator used in the present study is of medium size with a gross capacity of 125litre and is designed to work on LPG. The performance parameters investigated is the refrigeration effect in certain time. The refrigerator worked efficiently when LPG was used as refrigerant instead of CFC 12. The evaporator temperature reached -5 °C with and an ambient temperature of 12 °C. Also from the experiment which done in atmospheric condition, we can predict the optimum value of cooling effect with the suitable operating condition of regulating valve and capillary tube of the system. The results of the present work indicate the successful use of this propane-butane mixture as an alternative refrigerant to CFC 12 in domestic refrigerator.*

Keywords: *LPG Refrigeration, LPG, Capillary tube, Evaporator, COP, VCR, Refrigerating Effect.*

1. INTRODUCTION

The term 'refrigeration' in a broad sense is used for the process of removing heat (i.e. cooling) from a substance. 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 continued extraction of heat from a body, whose temperature is already below the temperature of its surroundings. For example, if some space (say in cold storage) is to be kept at $-2\text{ }^{\circ}\text{C}$, we must continuously extract heat which flows into it due to leakage through the walls and also the heat, which is brought into it with the articles stored after the temperature is one reduced to $-2\text{ }^{\circ}\text{C}$. Thus in a refrigerator, heat is virtually being 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 (say electrical motor) is regularly required to drive a refrigerator. Theoretically, the refrigerator is a reversed heat engine, or a heat pump which pumps heat from cold body and delivers to a hot body. The substance which works in a heat pump to extract heat from a cold body and to deliver it to a hot body is called refrigerant. When people hear the word refrigeration they immediately think of the refrigerator in their kitchen. However there are actually quite a few different kinds of refrigeration out there and they each have their own methods of functioning. One particular type of refrigeration is industrial refrigeration. This type of refrigeration is typically used for cold storage, food processing, and chemical processing. The equipment is very large and made of industrial stainless steel. Industrial refrigeration, which frequently uses ammonia refrigeration to maintain temperature, is necessary for computer, foodstuffs, blood, vaccines, and quite a few other goods that must maintain a constant and steady temperature at all times.

2. EXPERIMENTAL SETUP



Fig. 1: Experimental Setup-1



Fig.2: Experimental Setup-2

A rectangular box was used to carry out the evaporation process. The box was insulated with the help of thermocoal to produce better refrigerating effect. The copper tube was installed inside the rectangular box that acts as a refrigerating chamber. High pressure LPG (pressure about 50 to 90psi) was discharged through the high pressure pipe from the LPG cylinder. A pressure gauge was used to regulate the pressure. This LPG was directly fed to the throttle valve from the high pressure pipe. The high pressure gas from the cylinder was expanded to a low pressure and low temperature in this process. The process was carried out by us in gas expansion type gas valve. This low temperature gas was passed through the copper tube in the refrigerating chamber that absorbs heat from the substances placed inside the chamber, and thus produces a refrigerating effect. The gas that was coming out of the chamber was directly fed to the burner.

In the current study, the high pressure LPG (12bar) from the cylinder has been regulated to low pressure (5.17bar and 5.10 bar), then passed to the throttle valve. The evaporator box temperature has been recorded in equal interval of time when the system was operated. The inlet and outlet pressure of the LPG through the capillary tube and the temperatures of water that was being placed in the box were noted at both ends. The experimental setup has been run for 90 minutes and each data has been noted after an interval of 15 minutes. The physical dimensions of the developed model were shown below.

Physical dimensions of the experimental setup

<i>Pressure of the LPG cylinder</i>	<i>50-90psi</i>
<i>Bore diameter of Capillary tube</i>	<i>0.36mm</i>
<i>Evaporator box</i>	<i>Length: 360mm, Breadth: 135mm, Height:240mm</i>
<i>Thickness of thermocol sheets</i>	<i>15mm</i>
<i>Thermal conductivity of thermocol</i>	<i>$K_t=0.02W/m.k$</i>
<i>The measuring range of Pressure gauge</i>	<i>500psi.</i>

Table. 1: Physical setup

Specifications

1. Copper Tubes: According to the pressure 100psi the outside diameter of tube = 7 mm and the thickness of the tube is = 1.5mm.
2. Capillary tube: By considering the pressure and flow rate we select the capillary tube with internal diameter 0.78 mm and length 2.95m.
3. Evaporator: We have used same evaporator which is used in domestic refrigerator i.e. Plate and tube type evaporator. The evaporator has following dimensions: Length = 330 mm, Breadth = 270mm and Height = 140mm.
4. Refrigerator: Size of Refrigerator box: 325 X 265 X 135

3. INSTRUMENTATION

LPG Cylinder:

LPG is a mixture of butane and iso-butane. It is generally stored at 12.7 bar for house hold purpose cylinder. By using a suitable regulator LPG is sent into capillary tube. LPG is used as a fuel for domestic, industrial, horticultural, agricultural, cooking, heating and drying processes. LPG can be used as an automotive fuel or as a propellant for aerosol, in addition to other specialist applications LPG can also be used to provide lighting through the use of pressure lanterns.



Fig.3: LPG gas cylinder

Capillary Tube:

The capillary tube is the commonly used throttling device in the domestic refrigeration. The capillary tube is a copper tube of very small internal diameter. It is of very long length and it is coiled to several turns so that it would occupy less space. The internal diameter of the capillary tube used for the refrigeration applications varies from 0.5 to 2.28 mm (0.020 to 0.09 inch). The capillary tube is shown in picture. The decrease in pressure of the refrigerant through the capillary depends on the diameter of capillary and the length of capillary. Smaller is the diameter and more is the length of capillary more is the drop in pressure of the refrigerant as it passes through the capillary tube.



Fig.4: Capillary tube

Evaporator:

The evaporators are another important parts of the refrigeration systems. Through the evaporators the cooling effect is produced in the refrigeration system. It is in the evaporators when the actual cooling effect takes place in the refrigeration systems. For many people the evaporator is the main part of the refrigeration system, consider other part as less useful. The evaporators are heat exchanger surface that transfer the heat from the substance to be cooled to the refrigerant, thus removing the heat from the substance.



Fig.5: Evaporator

The evaporators are used for wide variety of diverse application in refrigeration and hence the available in wide variety of shape, sizes and designs. They are also classified in different manner depending on the method of feeding the refrigerant, construction of the evaporator, direction of air circulation around the evaporator, application and also the refrigerant control. In the domestic refrigerators the evaporators are commonly known as freezers since the ice is made in these compartments. In the evaporators the refrigerant enters at very low pressure and temperature after passing through the capillary tube. This refrigerant absorbs the heat from the substance that is to be cooled so the refrigerant gets heated while the substance gets cooled. Even after cooling the substance the temperature of the refrigerant leaving the evaporator is less than the substance. In the large refrigeration plants the evaporator is used for chilling water.

Pressure Gauges:

Many techniques have been developed for the measurement of pressure and vacuums. Instruments used to measure pressure are called pressure gauges or vacuum gauges.



Fig.6: Pressure gauge

High Pressure Pipes:

The range of high pressure pipes covers most application where there is a requirement to transfer gas at high pressure. They consist of a steel pipe with steel ball fitted to both ends. Two swiveling connection nipples press these balls against the seating of the connecting hole and thus sealing against gas leakage.

All pipes are pressure tested to 100 M Pa (14,500 psi) over recommend



Fig.7: High pressure pipe

High Pressure Regulator:

This type of regulator is used to send high pressure gas from the cylinders. These are mainly used in functions to Bhatti stoves.



Fig.8: High pressure regulators

4. CONSTRUCTION OF THE LPG REFRIGERATOR

The LPG refrigerator shown in fig.8. We make the one box of the plywood. The plywood sheet size is 12mm for used the LPG refrigerator. The size of the refrigerator is 724*457*381 mm³. The evaporator is fitted on the upper portion of 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.



Fig.9: Construction of the LPG refrigerator

The schematically diagram of the LPG refrigeration system is shown in next page. The gas tank is connect by pipes to the capillary tube. The capillary tube is fitted with evaporator. The evaporator coiled end is connect 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.

5. EXPERIMENTAL PROCEDURE

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

LPG is stored in the LPG cylinder under high pressure. When the gas tank of regulators is opened then high pressure LPG passes through the high pressure pipe. This LPG is going by high pressure gas pipe to capillary tube.

High pressure LPG is converted in low pressure at capillary tube with enthalpy remains constant.

After capillary tube, low pressure LPG is passed through the evaporator. LPG is converted into low pressure and temperature vapor form and passes the evaporator which absorbs heat from the chamber. Thus the chamber becomes cool down. Thus we can achieve cooling effect in refrigerator.

After passing through the evaporator low pressure LPG is passed through the pipe to burner. And we can use the low pressure of LPG in burning processes. The LPG Refrigerator is work on the simple Vapor Compression Refrigeration system. The working of VCR system is as follows:

Process 2-3: When the compressor is started, it draws the low pressure vapour from the evaporator at state 2 and compresses it isentropically to sufficiently high pressure up to state 3. Since in compression work is done on the vapour, its temp also increases and hence it is converted into low pressure adiabatically i.e. enthalpy remains constant.

After capillary tube, this low pressure LPG is passed through evaporator. In the evaporator LPG is converted into low pressure and temperature form which it absorbs the heat from the cooling chamber. Thus the cooling chamber cools down.

Process 3-4: Hot vapour from compressor under pressure is discharged into the condenser where condenser cooling medium usually water or surrounding air is absorb the heat from hot vapour. This converts the hot vapour into liquid and the liquid is collected in liquid receiver at state 4.

Process 4-1: The liquid from the liquid receiver at high pressure is then piped to a refrigerant control valve which regulates the flow of liquid into the evaporator. This control valve, while restricting the flow, also reduces the pressure of the liquid with the result the liquid change into vapour of low dryness fraction represented by state 1. During this process the temperature of the refrigerant reduces corresponding to its pressure.

Process 1-2: Finally, the low pressure, low temperature refrigerant passes through the evaporator coil where it absorbs its latent heat from the cold chamber or from brine solution at constant pressure and converts into vapour at state 2. It is again supplied to compressor. Thus, the cycle is completed.

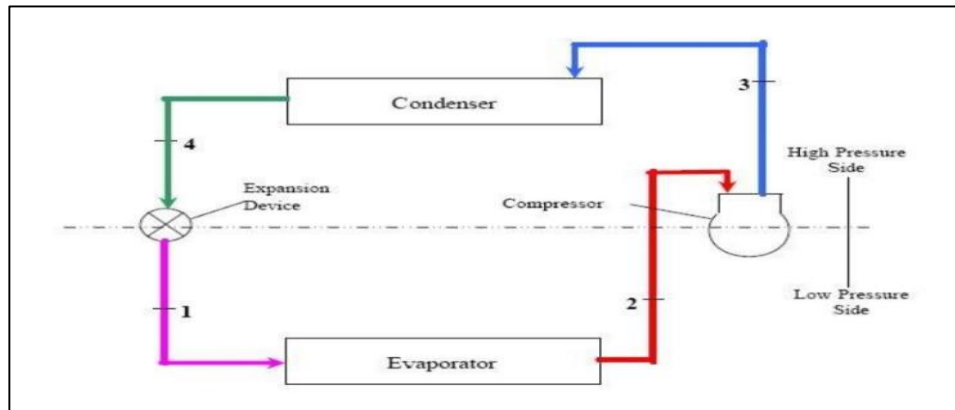


Fig.10: Schematic diagram of simple VCRs

The idea behind working of LPG refrigeration is to absorb heat from surrounding by using the evaporation of a LPG. The pressure of LPG which is stored in cylinder is at about 80 psi. We are lowering this pressure of LPG up to pressure 15 psi by using capillary and so that cooling is done on surrounding by absorbing heat isentropically. Pressure of LPG in cylinder is high, when the regulator of gas tank is opened then high pressure LPG passes through gas pipe. After that this high pressure LPG goes in the capillary tube from high pressure pipe. In the capillary tube this high pressure LPG is converted into low pressure and hence low temperature because of expansion of LPG gas in capillary tube.

Thus we can get refrigerating effect in refrigerator. After that the low pressure LPG from evaporator is passed to the burner through high pressure pipe and we can use this low pressure LPG for burning for further application. In this project we use recompressed LPG cylinder instead of compressor. In this way we can achieve refrigerating effect from this system. The actual setup and construction of LPG refrigeration system is shown in the following figure.

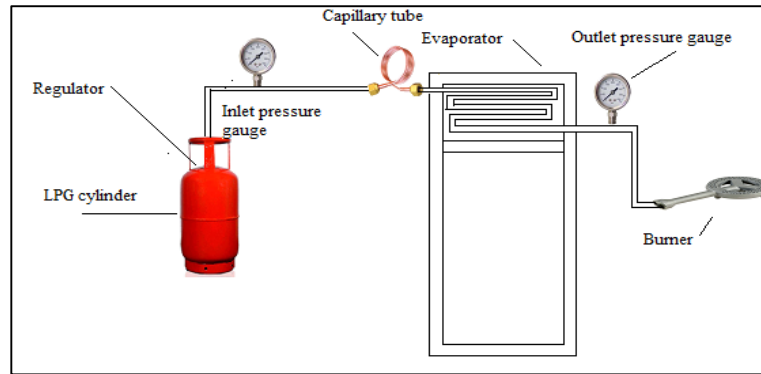


Fig.11: LPG Refrigeration system Actual Setup

Readings:

The properties of LPG at 5.525 bars are Enthalpy $h_1 = 430.3\text{kJ/kg}$

The properties of LPG at 1.22 bars are Enthalpy $h_f = 107.3\text{kJ/Kg}$

$h_2 = 294.8\text{ kJ/kg}$, $h_g = 482.3\text{ kJ/kg}$, $h_3=562.46\text{kJ/kg}$

So the refrigerating effect is, $RE=h_3-h_2=562.46 -294.8$

$$=267.66\text{ kJ/kg}$$

We have the volume flow rate of LPG is 0.1 liter per min. and the specific volume of LPG at 1.56 bar pressure is $1.763 \times 10^{-3}\text{ m}^3/\text{Kg}$. So

$$\text{mass flow rate of LPG is} = 0.0001/1.763 \times 10^{-3}$$

$$= 0.0567\text{ Kg/min m}$$

$$= 9.45 \times 10^{-4}\text{ Kg/sec}$$

For calculating the COP of the system, we required the work input. For work input we have a 4.5Kg. LPG cylinder. Hence, input work is the amount of power required for filling 1cylinder. From the PCRA energy auditre port power required to refill1 cylinder is 3.1354kWh.

Therefore, for filling 1kg of LPG power required is,

$$=3.1354/14.5$$

$$=0.2162\text{kWh}$$

We run the setup for 1.5hr. for that power is= $0.2162 \times 1000 / [(9.45 \times 10^{-4}) \times 5400]$

$$=42.39\text{W}$$

S.R NO	ININLET PRESSURE (Bar)	OUTLET PRESSURE (Bar)	TIME (min)	EVAPORATOR TEMP. (°C)
1	5	0.8	10	34.5
2	5	0.8	20	31.6
3	5	0.8	30	28.1
4	5	0.8	40	25.7
5	5	0.8	50	21.9
6	5	0.8	60	18.8
7	5	0.8	70	16.4
8	5	0.8	80	14.8
9	5	0.8	90	12.2

Table 2

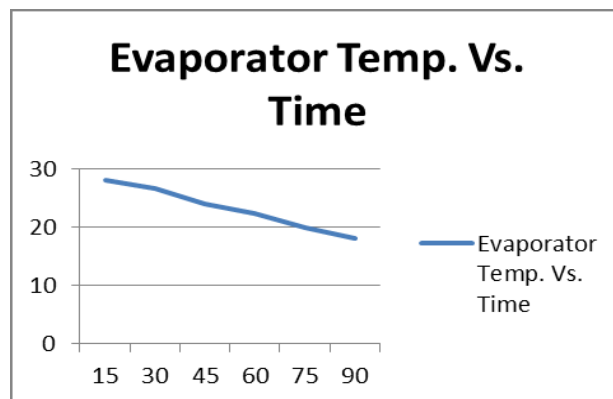


Fig.12: Evaporator temperature vs. Time

COP of the LPG Refrigeration System:

$$\begin{aligned}
 \text{COP} &= RE / W \\
 &= 267.66 / 42.39 \\
 &= 6.3
 \end{aligned}$$

After finding out the COP of the LPG refrigerator we found out the heat liberated by LPG after burning in the burner with the burner efficiency of 92 %.

$$\text{Mass flow rate of LPG (M)} = 9.45 \times 10^{-4} \text{ Kg/sec}$$

$$\text{Specific calorific value of LPG (CV)} = 46.1 \times 10^3 \text{ KJ/sec}$$

$$\text{Heat liberated by LPG } QL = M \times CV$$

$$QL = (9.45 \times 10^{-4}) \times (46.1 \times 10^3)$$

$$QL = 43.56 \text{ W}$$

6. RESULT

The performance refrigerating system was evaluated by analyzing the COP of the system. The refrigerating effect produced and work input to the developed system was used to find out the COP of the system. When the inlet gas pressure was 5.52 bar, the refrigerating effect was found to be 267.66 KJ/Kg and the COP was 6.3.

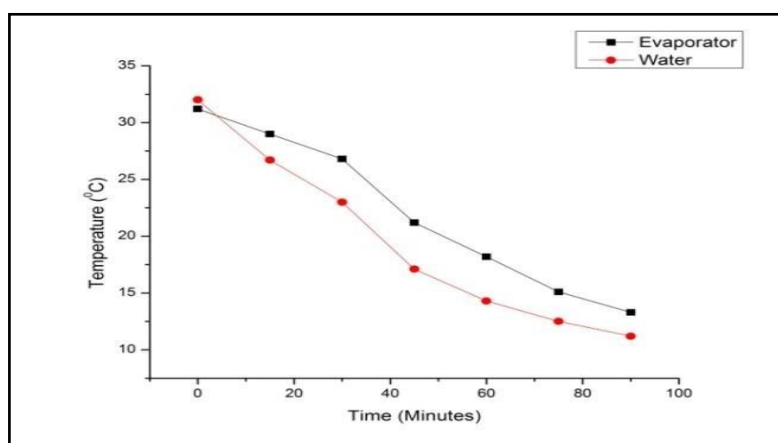


Fig.13" Time Vs Temperature of the evaporator box and water for inlet gas pressure of 5.52bar

7. CONCLUSION

The aim of the LPG refrigerator was to use LPG as a refrigerant and utilizing the energy of the high pressure in the cylinder for producing the refrigerating effect. We have the LPG at a pressure of 12.41 bars in Domestic 14.5 kg cylinder equipped with a high pressure regulator and this pressure has reduced up to 1.41 bars with the help of capillary tube. But if we use a low pressure regulator as is the practice in conventional domestic LPG gas stove, the pressure of LPG after the expansion device and before the burner would be different. So we have calculated the refrigerating effect with the help of changes in properties of LPG (pressure, temperature, and enthalpy) before and after the evaporator using high pressure regulator and the amount of refrigerating effect is determined. With this energy input the COP of the LPG refrigerator is 5.08 and it is greater than the domestic refrigerator. But in the

future scope the result may differ if energy input for 1Kg of LPG production, would be taken from the energy audit report of any refinery. This system is cheaper at initial as well as running cost. It does not require an external energy sources to run the system and no moving part in the system. So maintenance cost is also very low. This system is most suitable for hotel, industries, refinery, chemical industries where consumption of LPG is very high. 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 whereas 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.

Cooling capacities were obtained order of about three- to four fold higher for LPG than those for R- 12. Capillary tube. 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, High COP values were obtained. No operation problems have been encountered with compressor. The use of LPG as a replacement refrigerant can contribute to the solution of (ODP) problem and global warming potential.

8. FUTURE SCOPE

- 1) *It can be useful in remote parts where electricity is not available.*
- 2) *It can play an important role in restaurants where continuously cooling and heating is required.*
- 3) *It can be used in automobiles running on LPG or other Gaseous fuels for air conditioning.*

ACKNOWLEDGEMENT

I have a great pleasure in presenting this project report on " LPG REFRIGERATION SYSTEM WITH ZERO OPERATING COST"

and to express my deep regards toward those who have offered their valuable time and guidance in my hour of need because when any work is to be successfully completed, it should be with guidance from many persons.

I would like to express my sincere and whole hearted thanks to my guide "Prof. A.M.Salwe" without whose support I was unable to express my ideas in this project.

I also thanks Head Of Department "Prof. P.S.Kachare" for this support and encouragement. Our sincere thanks to the Principle "Dr. T.K.Nagaraj" who provide us facilities during the project work.

I am also glad to express my gratitude and thanks to my parants and my friends who directly or indirectly support me for completion of this project

REFERENCES

- [1] M.A Hammad, and M.A Aslaad, "The use of hudrocarbon mixture as refrigeration in domestic refrigerator", *Applied Thermal Engineering*, vol. 19, no. 11. pp. 1181-1189, Nov. 1999.
- [2] A Bazkrance and P. K. Mathew, "A performance comparison of vapour compression refrigeration system using eco friendly refrigeration of low global warming potential", *Int Jrnl of Scientific and Research Publication.*, vol. 2, no. 9, ISSN 2250- 3153, Sept 2012.
- [3] R.W James and J.F. Missenden, "The use of propane in domestic refrigeration", *Institute of environment engineering*, vol. 4, London, Oct 1991.
- [4] A. Bilal and A. A. Salem, "Assessment of LPG as a possible alternative toR-12 in domestic refrigeration energy conversion & management", *Energy Conversion and Management*, vol. 44, no. 3, pp. 381-388, Feb 2003.
- [5] S. Mohanraj, S.Jayaraj, C.Murlidharan and P.chandrasekar, "Enviromental investigation of R290/R600 a mixture as an alternative to R134 in domestic refrigerator", *Int. Jrnl of Thermal Science*, vol. 48, no. 5, ,pp. 1036-1042 , May 2009.
- [6] S. Wongwise and N. Chimres, "Experimental study of hydrocarbon mixture to replace HRC 134 in a domestic refrigerator", *Energy Conversion and Management*, vol. 46, no. 1, pp. 85-100, Jan. 2005.
- [7] S. S. Punia and J. Singh, "Experimental investigation on the performance of coiled adiabatic capacity tube with LPG as refrigeration", *Int. Jrnl. of Mechanical and Production Engineering Research and Development (IJMPERD)*.