

# DESIGN OF LPG REFRIGERATION SYSTEM AND COMPARATIVE ENERGY ANALYSIS WITH DOMESTIC REFRIGERANT



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## ABSTRACT

This project investigates the result of an experimental study carried out to determine the performance of domestic refrigerator when a liquefied petroleum gas (LPG) which is locally available which comprises of 24.4% propane, 56.4% butane and 17.2% isobutene which is varied from company to company is used as a Refrigerant. The LPG is cheaper and possesses an environmental friendly nature with no Ozone Depletion Potential (ODP) and no Global Warming Potential (GDP). It is used in world for cooking purposes. The refrigerator used in the present study 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 a refrigerant instead of R134a. The evaporator temperature reached 15°C with an ambient temperature of 35°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

**Keywords:** LPG Refrigeration, Capillary tube, Evaporator, COP, Vapour Compression Refrigeration system, Refrigerating effect.

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## I. INTRODUCTION

### 1.1 Problem Statement

The people in rural areas require refrigeration for a variety of socially relevant purposes such as cold storage or storing medical supplies and domestic kitchens this project has the novelty of using LPG instead of electricity for refrigeration. The primary work of this project is to use the the LPG (liquefied Petroleum Gas) as refrigerant instead of various refrigerants like R134a which cause Ozone layer depletion and global warming and also to check the effect of different diameter of capillary tube on the whole system and Compare it with the traditional refrigeration system.

### 1.2 Objectives

- Implementation of capillary tube in LPG system
- The basic idea behind LPG refrigeration is to use the evaporation of a LPG to absorb heat.
- To identify the form of residual waste in traditional refrigeration system.
- To study the properties of capillary tube.

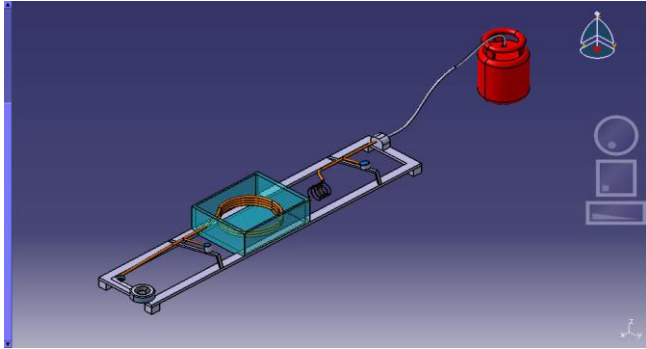
- Compare the important characteristics between LPG refrigeration system and Domestic refrigeration system and to distinguish between the current existing refrigerator cost and estimated cost of LPG refrigerator

## II. EXPERIMENTAL SETUP

### 2.1 Working Principle

It works on the principle that during the conversion of LPG into gaseous form, expansion of LPG takes place. Due to this expansion there is a pressure drop and increase in volume of LPG that results in the drop of temperature and a refrigerating effect is produced. This refrigerating effect can be used for cooling purposes. So this work provides refrigeration for socially relevant needs as well as replaces global warming creator refrigerants. Conventional VCR (Vapour Compression Refrigeration System) uses LPG as refrigerant and produced the refrigerating effect. Butin our proposed very simple type of refrigeration system in which the high pressure LPG is passing through a capillary tube and expands. After expansion the phase of LPG is changed and converted from liquid to gas and then it passes through

the evaporator where it absorbs the heat and produces the refrigerating effect. After evaporator it passes through the gas burner where it burns.



**Figure III:- LPG Setup**

## 2.2 Actual System Setup

- LPG is extracted at high pressure in liquefied state from the storage device. Its pressure and flow rate is controlled by a valve connects it to the evaporator at requisite pressure in requisite quantity.

- An evaporator is housed through which LPG flows. It gets converted from liquefied state to gaseous state and expands. So it absorbs heat in the form of latent heat. Due to this process, heat from surrounding is absorbed so cooling effect is produced.

- This effect is magnified by an evaporator. A network of pipes containing gas is covered by thin and closely spaced fins which help in effective and fast cooling. The insulating material helps in storing the cooling effect for a longer period of time.

- The LPG leaves the evaporator in gaseous form; it is then directed towards the burner, engine, or any other application where it is to be used. Thus, no LPG is consumed for cooling purpose.



**Figure 2:- Actual Setup**

## III. SPECIFICATIONS OF COMPONENTS

### 3.1 Copper pipe :-

- ▶ Dimension :- Diameter = 6mm.,

Length = 8m.

- ▶ Material :- Copper



**Figure 3:- Copper pipe**

### 3.2 Pressure gauge :-

- ▶ Pressure gauge range :-0 to 150 psi.
- ▶ Type :- Compound
- ▶ Company Name :- NovaTech



**Figure III:- Pressure gauge**

### 3.3 Capillary Tube :-

Dimension :-Diameter = 0.36mm. ,  
Length = 800mm.



**Figure 5:- Capillary Tube**

### 3.4. Brass Connectors :-

- ▶ Material :- Brass



**Figure 6:- Brass Connectors**

**3.5 T- joint :-**

- ▶ Material :- Copper
- ▶ Dimension :- Diameter = 0.36mm.



**Figure 7:- T- joint**

**IV. OPERATIONAL PARAMETERS**

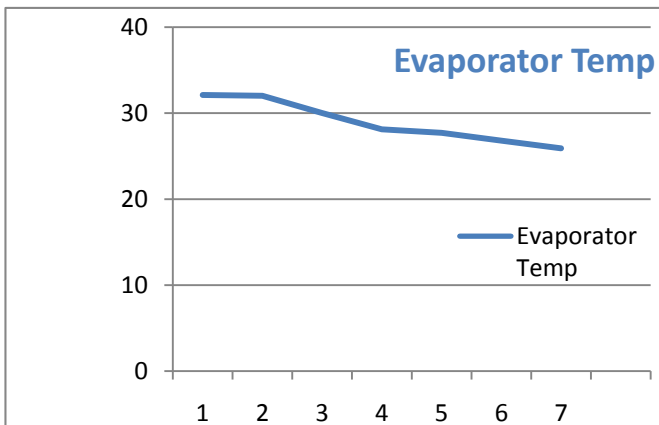
- ▶ Size of Refrigerator: 500 X 320 X 320
- ▶ Initial temperature of evaporator at the time of experiment: 32.1 °C

**4.1 Observation Table**

Inlet Pressure (P <sub>1</sub> )		Outlet Pressure (P <sub>2</sub> )		Room Temp. (T <sub>1</sub> , °C)	Evaporator Temp. (T <sub>2</sub> , °C)	Time (Min)
Psi	Bar	Psi	Bar			
80	5.51	20	1.37	32.1	32.1	0
80	5.51	20	1.37	32.1	30	1.12
80	5.51	20	1.37	32	28.1	1.36
80	5.51	19.70	1.35	32	27.7	2.24
80	5.51	19.50	1.34	31.9	26.8	4.35
80	5.51	19.08	1.31	31.7	25.9	7.35

**Table-1: Observation Table**

**4.2 Graph**



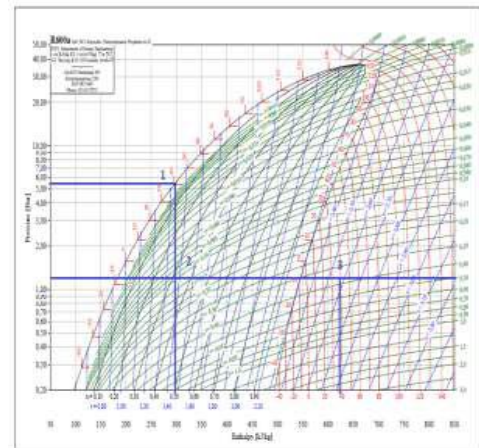
**Graph 1:- Evaporator Temp. v/s Time (min)**

**V. CALCULATIONS**

**5.1 Calculations of LPG refrigerator**

The properties of LPG at 5.516 bars are Enthalpy  $h_1 = 307.3 \text{ KJ/Kg}$

The properties of LPG at 1.316 bars are Enthalpy  $h_3 = 630.3 \text{ KJ/Kg}$



**Figure 8:- p-h diagram of LPG Refrigerator**

$$\begin{aligned} \text{So the refrigerating effect is} &= h_3 - h_2 \\ &= 630.3 - 307.3 \\ &= 323 \text{ KJ/Kg} \end{aligned}$$

For calculating the COP of the system, we required the work input. For work input we have a 14.5 Kg. LPG cylinder. Hence, input work is the amount of power required for filling 1 cylinder. From the PCRA energy audit report power required to refill 1 cylinder is 3.1354kWh.

$$\begin{aligned} \text{Therefore, for filling 1 kg of LPG power required is,} \\ &= \frac{3.1354}{14.5} \end{aligned}$$

$$\begin{aligned} \text{We run the set up for 1 hr,} \\ &= 0.2162 \times \frac{1000}{\left(\frac{9.45}{10000}\right) \times 3600} \\ &= 63.55 \text{ W} \end{aligned}$$

**5.1.1 COP OF THE LPG REFRIGERATION SYSTEM<sup>[10]</sup>**

$$\begin{aligned} \text{COP} &= \frac{(h_3 - h_2)}{w} \\ &= \frac{630.3 - 307.3}{63.55} \\ &= 5.08 \end{aligned}$$

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 %.

Heat liberated by LPG  $Q_L = m \times cv$  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  $1.763 \times 10^{-3} \text{ m}^3/\text{kg}$

$$\begin{aligned} \text{So mass flow rate of LPG is} &= \frac{0.0001}{1.763 \times 10^{-3}} \\ m &= 0.0567 \text{ kg /min} \\ m &= 9.45 \times 10^{-4} \text{ kg /sec ; } cv = 46.1 \text{ MJ/Kg} \\ Q_L &= m \times cv \\ Q_L &= 9.45 \times 10^{-4} \times 46.1 \times 10^3 \end{aligned}$$

$$= 43.56 W$$

## 5.2 Cop Of Domestic Refrigerator

COP for a domestic refrigerator using the R134a refrigerant of capacity of 165 liters and a compressor pressure of 10 bars and evaporator pressure of 1.4 bars.

The work done on the compressor =  $-54 \text{ KJ/Kg}$ .

The heat absorbed by the evaporator =  $137 \text{ KJ/Kg}$

and that rejected by the condenser =  $-191 \text{ KJ/Kg}$

Refrigeration effect of domestic refrigerator =  $109.1 \frac{\text{KJ}}{\text{Kg}}$

## 5.3 The Coefficient of Performance of the refrigerator (COP)

COP :- It is defined as the heat absorbed in the evaporator divided by the work done on the compressor always presented as a positive value even though the work done is negative.

$$\begin{aligned} \text{COP} &= \frac{\text{Heat absorbed in the evaporator}}{\text{Work done on the compressor}} \\ &= \frac{137}{54} \\ &= 2.53 \end{aligned}$$

## 5.4 Comparison Of LPG Refrigerator With Domestic Refrigerator

REFRIGERATOR	COP	Refrigeration effect
LPG REFRIGERATOR	5.08	323 KJ/Kg
DOMESTIC REFRIGERATOR	2.53	109.1 KJ/Kg

**Table - 1 Comparison Table**

- Cop of a domestic refrigerator is normally up to 2.53 which is lesser than the LPG refrigerator.
- Domestic refrigerator required high input power than LPG refrigerator.
- Also there are more moving parts in domestic refrigerator and not eco-friendly.
- Domestic refrigerator requires more maintenance and operation is noisy.

## VI. ADVANTAGES AND APPLICATION

- No moving parts.
- No vibration or noise on small system.

- Small systems can operate without electricity using only heat; large systems require power for chemical pumps.
- Can make use of waste heat.
- Use of LPG as a refrigerant also improves the overall efficiency of by 10 to 20%
- The ozone depletion potential (ODP) of LPG is 0 and Global warming potential (GWP) is 8 which is significantly negligible as compare to other refrigerant.
- A part from environment friendly, use of LPG also gives us lot of cost advantages.
- There is 60% reduction in weight of the system due to higher density of LPG.
- This fridge works when electricity is off.
- Eliminates the compressor and condenser.

## Limitations

- Potential refrigerant leaks.
- Operates under limited vibration and orientations.
- Complicated and difficult to service and repair.
- System is very bulky
- Efficiency is poor.

## Applications

- The system can universally be used in industrial central cooling and domestic refrigeration and air conditioning as well.
- Can be used in automobiles running on LPG or other Gaseous fuels for air conditioning.
- It can play an important role in restaurants where continuously cooling and heating is required.
- It can be used in chemical industries for refrigeration purpose.
- It can be useful in remote parts where electricity is not available.
- It can be used in refineries where consumption of LPG is high.
- The system can universally be used in industrial central cooling and domestic refrigeration and air conditioning as well.
- It can be used in automobiles running on LPG or other Gaseous fuels for air conditioning.
- It can be useful in remotes parts where Electricity is not available.
- Cooling and storage of essentials in remote areas and in emergency vehicles, such as storage of essential bio-chemicals, injections, etc in an ambulance, is easily possible.
- It can be used for zero cost air-conditioning of spaces like airports, shopping malls, etc which have their own gas turbine power-plants.

## VII. FUTURE SCOPE

An introduction of new product in the field of refrigeration is expected and 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 hold good application in an LPG car air conditioning.

### VIII. 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 bar in Domestic 14.5 kg cylinder equipped with a high pressure regulator and this pressure has reduced up to 1.41 bar 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.

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