LPG REFRIGERATOR

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ABSTRACT

Supply of continuous electricity is still not available in several areas of the country and the world. At such places, this work will be helpful for refrigeration of food, medicines, etc. This paper 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 use of LPG for refrigeration purpose can be environment friendly since it has no ozone depletion potential (ODP). Usually LPG is used as a fuel for cooking food in houses, restaurants, hotels, etc. and the combustion products of LPG are CO2 and H2O. In this project we have designed and analysed a refrigerator using LPG as refrigerant. LPG is available in cylinders at high pressure. When this high pressure LPG is passed through the capillary tube of small internal diameter, the pressure of LPG is dropped due to expansion and phase change of LPG occurs in an isenthalpic process. Due to phase change from liquid to gas latent heat is gained by the liquid refrigerant and the temperature drops. In this way LPG can produce refrigerating effect for a confined space. From experimental investigations, we have found that the COP of a refrigerator which uses LPG is higher than a domestic refrigerator.

Keywords: LPG refrigerator, capillary tube, evaporator coil, Copper pipe, refrigeration effect, COP.

INTRODUCTION

Due to the huge demand of electricity over the world, we think of recovering the energy which is already spent but not being utilized further, to overcome this crisis with less 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 COST FREE Cooling Systems. Although government agencies are not able to continuously supply a major portion of electricity in both the urban as well as in rural areas. Still the people in these regions 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. This solution is convenient for refrigeration in regions having scares in electricity. The term ‘refrigeration’ in a broad sense is used for the process of removing heat (i.e. Cooling) from a substance. we were able to build a reasonably reliable machine by the end of nineteenth century for the refrigeration jobs. But with the advent of efficient rotary compressors and gas turbines, the science of refrigeration reached its present height. When a liquid vaporizes rapidly, it expands quickly. According to the second law thermodynamics, this process can only be performed with the supply of some external work. It is thus obvious, that supply of power (say electrical motor) is regularly required to drive a refrigerator. The substance which work in a heat pump to extract heat from a cold body and to deliver it to a hot body is called “refrigerant”.

Conventional VCR (Vapour Compression Refrigeration System) uses LPG as refrigerant and produced the refrigerating effect. But in 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.

PROPERTIES OF LPG

Colorless.

Odorless - (It's normal to odorize LPG by adding an odorant prior to supply to the user, to aid the detection of any leaks).

Flammable.

Heavier than air.

Approximately half the weight of water.

Nontoxic but can cause asphyxiation.

A good mixture: LPG is mainly Propane (C_3H_8), Butane (C_4H_{10}) or a mixture of Propane/Butane.

Boiling Point: LPG's boiling point ranges from -42 ˚C to 0 ˚C depending on its mixture percentage of Butane and Propane

OBJECTIVES

- Use liquid LPG as a refrigerant.
- Run LPG refrigerator without electricity by eliminate the compressor and condenser.
- To produce the ecofriendly refrigerator.
- To determine the COP of the refrigerator using LPG as a refrigerant.

WORKING PRINCIPLE OF LPG REFRIGERATOR

This work replaces the conventional refrigerant by LPG as a cooling medium in a refrigerator. It works on the principle that during the change of LPG from liquid into gaseous form, expansion of LPG takes place. Due to this expansion pressure drop occurs and increase in volume of LPG. It results in the drop of temperature and a refrigerating effect is produced and it is used for cooling purposes. In this refrigeration system the high-pressure LPG is passed through capillary tube and it expands, after expansion the phase change occurs and it convert from liquid to gas. Then it passes through the evaporator where it absorbs the latent heat of the stored product and produces the refrigerating effect.

WORKING OF LPG REFRIGERATOR

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 vapour from 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 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-

110 psi. We are lowering this pressure of LPG up to pressure 15-40 psi by using capillary and so that cooling is done on surrounding by absorbing heat isentropically. The actual setup and construction of LPG refrigeration system is shown in the following figure.

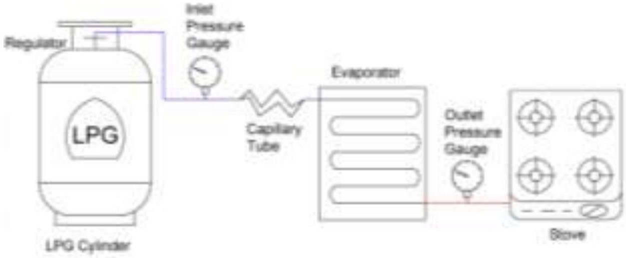

Fig.1: LPG refrigeration system

CONSTRUCTION OF LPG REFRIGERATOR

The LPG refrigerator is shown in the figure. We make the one box of the Thermo-coal sheet. The thermo-coal sheet size is 15mm used for the LPG refrigerator. The size of the evaporator is 365*240*150 mm^3. We kept the thermo-coal sheet box because the cold air cannot transfer from inside to outside of refrigerator. The gas cylinder is connected to high pressure regulator, which is connected to high pressure pipes. To the other end of the high pressure pipes pressure gauge is connected. To another end a copper tube is connected which is connected to the capillary tube. The capillary tube is fitted with evaporator. The evaporator coil end is connected to the stove by another high pressure pipe. One pressure gauge is put between capillary tube and cylinder and another is put at the end of the evaporator.

PARTS OF LPG REFRIGERATION

1. LPG cylinder:

LPG is a mixture of butane and isobutene. 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.2: LPG cylinder

2. 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. 3: Capillary tube

3. 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. 4: Evaporator

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.

4. 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. 5: Pressure Gauges

The most commonly used mechanical gauge is Bourdon type pressure gauge. This is Single Gauge Manifold Pressure Gauge. It is a stiff, flattened metal tube bent into a circular shape. The fluid whose pressure is to be measured is inside the tube. One end of the tube is fixed and another end is free to move inward or outward. The inward and outward movement of free end moves a pointer, through a linkage and gear arrangement, a dial graduated in pressure unit i.e. bar. Pressure gauge records the gauge records the gauge pressure which is the difference between fluid pressure and outside atmospheric pressure.

5. 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 100MPa (14,500 psi) over recommended working pressure.

Fig. 6: High Pressure Pipes

6. 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. 7: High Pressure Regulator

7. Strainer:

Refrigerant Strainer collect foreign materials and dirt in a refrigerant system at minimal pressure drop in order to minimize damage or to prevent malfunction of capillary tube.

Fig. 7: Strainer

EXPERIMENTAL SETUP

Fig. 8: Experimental Setup (Front view)

Fig. 9: Experimental Setup (Rear view)

EXPERIMENTAL READING

As we conducted an experiment with the system of initial pressure of 110 psi from LPG cylinder and output pressure of 40 psi to obtain refrigeration effect. The observations have been tabulated as shown in below Table 1 and also graphical representation of experiment i.e. Temperature vs. Time is shown below graph.

Time (Min)	Initial Pressure (Psi)	Delivery Pressure (Psi)	Temperature (°C)
5	110	41	37.2
10	110	40	30.3
15	110	41	26.7
20	110	40	23
25	110	40	19.1
30	110	36	16.4

Table 1: Temperature, Initial & Delivery Pressure with respect to time.

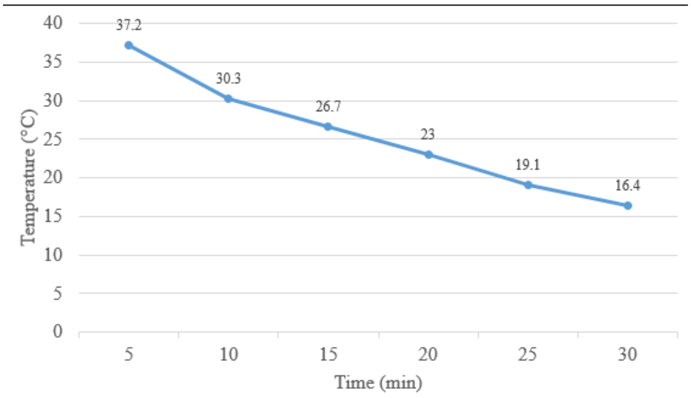

Chart 1: Temperature Vs Time

CALCULATION

Size of refrigerator: - 365×240×150 mm^2

Initial temperature of water: 37.2°C

Specific heat of LPG vapor is 1.495kJ/Kg K

Heat extracted from evaporator in 30 min. (Q_{eva}) = Heat gain by LPG (Q_{LPG})

(Q_{eva}) = Heat extracted from (water + surrounding air inside of evaporator + container + leakage)

m_w = mass of water = 0.1 kg

cp_w = specific heat of water = 4.180 KJ/kg. K

$(\Delta T)_W$ = 20.8°C……………..[37.2-16.4]

= 293.8K

m_c = mass of container =0.7 kg

c_{pc} = specific heat of aluminium container = 903 J/kg. K

$(\Delta T)_C$ = 20.8°C = 293.8K

(Q_{eva}) = $Q_w + Q_{air} + Q_{con} + Q_L$

We have taken 0.1 kg of water in an aluminum container of weight 0.07 kg. Since, there is very less amount of air so it is neglected. Leakage is also neglected because of packed covered box (ice box).

∴ $Q_{air} = 0$ & $Q_L = 0$

(Q_{eva}) = $Q_w + Q_{con}$

(Q_{eva}) = [mwcpw×(ΔT)] + [mccpc(ΔT)]

(Q_{eva}) = (0.1×4.180×293.8) + (0.07×9.03×293.8)

(Q_{eva}) = 122.8084 + 185.711

(Q_{eva}) = 308.5194 KJ

∴ Heat gained by LPG (QLPG) = 308.5194 KJ for 30 min.

For work input we have a LPG cylinder of 14.5 Kg. so the work input is amount of energy required for filling of 1 cylinder. A typical LPG bottling plant has the following major energy consuming.

1. LPG pumps
2. LPG compressors
3. Conveyors
4. Blowers
5. Cold repair facilities including painting
6. Air compressors and air drying units.

7. Transformer, MCC & DG sets
8. Firefighting facilities
9. Loading and unloading facilities

Some of the LPG bottling plants use a comprehensive monitoring technique for Keeping track of energy/Fuel Consumption on per ton basis. PCRA Energy Audit.

1. Consumption = 40×4200=168000kWh
2. For lighting energy consumption= 227340kWh
3. LPG compressor consumption= 153360 kWh

Total consumption for LPG pumps:

One pump having 40 kW motor and 96 m head or 150 cubic meter /hour discharge

Annual operating = 4200 hrs.

Annual energy 6 hrs. /day in 350 days

= 168000+227340+153360

= 548700 kWh

Per day consumption

= 548700/350

=1567.71 kWh

500 cylinders are refilled every day, so per cylinder electricity consumption.

=1567.71/500

=3.1354kWh

For filling of 1 LPG cylinder of 14.5 kg the power input is

= 3.1354 kWh………………[This data is from a typical LPG bottling plant]

So 1 kg of LPG is

= 3.1354/14.5

=0.2162 kWh = 216.2 Wh

Setup for ½ hour (30 min.) = 108.1 Wh

We run the set up for ½ hr.

= 108.1 / (9.45/10000) ×1800

= 63.55W

COP of the LPG refrigeration system:

COP = (Heat gain by LPG)/ Power input

COP = 308.5194/63.55

COP = 4.85

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, QL= $\dot{m} \times c_v$

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 1.763×10^{-3} m^3/Kg.

So mass flow rate of LPG is = $(0.1\times0.001)/1.763\times10^{-3}$

m = 0.0567 Kg/min

$$m = 9.45\times10^{-4}\ Kg/sec$$

$\therefore\ Q_L = \dot{m} \times c_v$

$\therefore\ Q_L = 0.0567 \times 46.1\times103$

$\therefore\ Q_L = 2613.87$ KJ

$\therefore\ Q_L = 43.56$ KJ/sec

$\therefore\ Q_L = 43.56$ W

ADVANTAGES OF LPG REFRIGERATOR

- Use of LPG as a refrigerant also improves the overall efficiency of 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 refrigerator work when electricity is off.
- Running cost is zero.
- Eliminates the compressor and condenser.

DISADVANTAGES OF LPG REFRIGERATOR

- Efficiency is poor.
- Leakage of LPG causes blast.
- Repairing and servicing of system is difficult.
- System is very bulky.

APPLICATIONS OF LPG REFRIGERATOR

- It can play an important role in restaurants where continuously cooling and heating is required.
- It can be used in refineries where consumption of LPG is high
- It can be used in automobiles running on LPG or other Gaseous fuels for air conditioning.
- 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.

CONCLUSION

The aim of the LPG refrigerator was to use LPG as a refrigerant and utilising the energy of the high pressure in the cylinder for producing the refrigerating effect. From the experiment we have conclude that the high pressure LPG gas stored in a cylinder at 12.41 bar with the weight of 14.5 kg equipped with a high-pressure regulator. when LPG gas released the pressure drop occurs and the weight decrease. With the help of capillary tube, the pressure will drop down to the 1 bar from the operational pressure 4.82 bar. Due to the pressure drop the refrigerating effect occurs in an evaporator. The refrigerating effect changes the properties of LPG before and after evaporator. Therefore, a conclusion we can use LPG as a refrigerant in a refrigeration. LPG will not harm the environment and the eco system. The potential of ozone layer depletion and global warming will be reduced due to usage of current refrigerant in a domestic refrigerator. Since we don’t have the actual amount of energy that will be consumed in producing 1 Kg of LPG in the refinery and were not available in any of the Energy Audit Report of Refinery, that’s why we have taken the energy input from refilling plant only. For energy input we have taken the amount of energy required for refilling 1 Kg of LPG in the bottling plant (PCRA energy audit report, HPCL LPG bottling plant Asauda Bahadurgarh (Haryana) Dec. 2006.) is 0.216 kWh. With this energy input the COP of the LPG refrigerator is 5.08 and it is greater than the domestic refrigerator.

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