PERFORMANCE EVALUATION OF LPG REFRIGERATION SYSTEM

This Project paper is submitted to the Department of Mechanical Engineering, Sonargaon University for partial fulfillment of requirements for the degree of Bachelor of Science in Mechanical Engineering

Supervised by:

Md. Mahedy Hasan
Lecturer Department of Mechanical Engineering Sonargaon University

Submitted By:

Md. Shohel Rana, BME1901017288
Abdulla Al Mamun, BME1803016422
Mohammad Kabir Hossain, BME1901017274
Md. Sajal Ahmmed, BME1901017277
Abu Kowsar, BME1702012005
Safiqul Islam Rasel. BME1901017172

Sonargaon University
147/I, Green Road,
Tejgaon, Dhaka-1215,
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ABSTRACT

According to the Bangladesh Government, the refrigerator is the 3rd heaviest consumer of power among household appliances. It is one of the few appliances that is running 365 days a year. Domestic refrigerators runs with refrigerants like CFC, R22, etc. Though R22 is better than CFC in terms of COP, but it also causes global warming and ozone depletion. To avoid this many researches are going on. Our project is about using Liquefied Petroleum Gas (LPG) as an alternative for the refrigerant. LPG also has the same effect of refrigerants but its COP is low. Though its COP is low, it doesn't cause global warming and ozone depletion

TABLE OF CONTENTS

LIST OF FIGURE

CHAPTER: 01

INTRODUCTION & OBJECTIVE

1.1 LPG refrigeration:

Due to the huge demand for 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. We know refrigerators became a daily part of our life. Its usage is increasing day by day. On the other side, its harmful effect on the environment also increases gradually. The climatic change and global warming demand accessible and affordable cooling systems in the form of refrigerators and air conditioners. We need to reduce this harmful effect, but we can't avoid using refrigerators. But we can use some other techniques to produce the refrigeration effect, which does not cause any global also increasing day by day, but its production rate remains the same. The usage of electricity should be reduced. It is estimated that the electricity consumption of refrigerators is high among other household appliances. The LPG refrigeration system does not require electricity. The only input is

high-pressure Liquefied Petroleum Gas. Our aim is to produce a Refrigeration effect bypassing LPG through a capillary tube and expanding. 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 the evaporator, it passes through the gas burner where it burns.

1.2 Objective:

- Use liquid LPG as a refrigerant.
- Run LPG refrigerator without electricity by eliminating the compressor and condenser.
- To find out the COP of the refrigerator using LPG as a refrigerant.
- To make a Refrigeration system without causing Ozone depletion.

CHAPTER: 02

LITERATURE REVIEW

2.1 Bilal A. Akashet. al.

Has conducted a performance test on the performance of liquefied petroleum gas (LPG) as a possible substitute for R12 in a domestic refrigerator. The refrigerator which is initially designed to work with R12 is used to conduct the experiment for LPG (30% propane, 55% N-Butene, and 15% isobutene) various mass charges of 50, 80, and 100gram of LPG were used during experimentation. LPG compares very well to R12. The COP was higher for all mass charges at an evaporated temperature lower than -15℃. Overall, it was found that at an 80gram charge, LPG had the best result when used in this refrigerator. The condenser was kept at a constant temperature of 47℃. Cooling capacities were obtained and they were in the order of about three two, and four-fold higher than LPG than those for R12

2.2 M. Fatouh et. al.

Investigated a 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. For 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 100g and capillary tube length of 4 m. Pull-down time, pressure ratio, and power consumption of LPG refrigerators were lower than those of R134a by about 7.6%, 5.5%, and 4.3%, respectively. The COP of the LPG refrigerator was 7.6% higher than that of R134a. The 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 a drop-in replacement for R134a, to have better performance, optimization of capillary length and refrigerant charge was needed.

CHAPTER: 03

THEORY & WORKING PROCEDURE

3.1 THEORY:

In Refrigeration cyclic process refrigerant is removed from the low-temperature reservoir and is thrown to high temperature. As per the second law of thermodynamics, the natural flow of heat is from high-temperature to low-temperature reservoirs. In the refrigeration process since the flow of heat is reserved, the external work has to be done on the system. The refrigeration cyclic process refrigeration is also the reverse of the thermodynamic power cycle or Carnot cycle in which the heat flows from a high-temperature reservoir to low temperature reservoir. Hence the cycle of refrigeration is also called as Reversed Carnot Cycle. There are two types of refrigeration cyclic process: The vapor cycle and the Gas cycle.

3.2 Vapor Refrigeration Cycle:

It is classified into 2 types: a**.** Vapor compression refrigeration cycle b. Vapor absorption refrigeration cycle.

3.2.1 Vapor Compression Refrigeration Cycle:

In a vapor compression system, an evaporator and a gas-liquid separator is received in a common casing, so that the gas-liquid separator and the evaporator are placed close to each other. Thus, it is possible to limit heat absorption of the liquid phase refrigerant from the atmosphere to reduce the heat loss upon discharge of the refrigerant from the gas-liquid separator. Also, it is possible to reduce pressure loss in the refrigerant passage between the gas-liquid separator and the evaporator.

3.2.2 Vapor Absorption Refrigeration Cycle:

Before the development of the vapor compression system of refrigeration, the vapor absorption system was very widely used. The vapor compression system replaced the vapor absorption system because it has a high coefficient of performance (COP). The vapor absorption system requires very less amount of electricity but a large amount of heat; hence it can be used very effectively in industries where very large stocks of the excessive stem are available. In such cases, there is not only effective utilization of steam but also lots of savings in electricity costs.

3.2.3 Gas Cycle:

Just as vapor is used for cooling in the vapor compression cycle and vapor absorption cycle, gas is used in the gas refrigeration cycle. When gas is throttled from very high pressure to lower pressure in the throttling valve, its temperature reduces suddenly while its enthalpy remains constant. This principle is in gas refrigeration systems. In the system instead of using Freon or ammonia as the refrigerant, the gas is used as the refrigerant. Throughout the cycle, there are no phase changes of the gas, which are observed in the liquid refrigerant. Air is the most commonly used gas, also called a refrigerant in this gas refrigeration cycles

3.3 In Vapor compression Refrigeration Cycle:

Compression: The vapors of refrigerants enter the compressor and get compressed to high pressure and high temperature. During this process, the entropy of the refrigerant ideally remains constant and it leaves in a superheated state.

Condensation: The superheated refrigerant then enters the condenser where it is cooled either by air or water due to which its temperature reduces, but pressure remains constant and gets converted into a liquid state.

Expansion: The liquid refrigerant then enters the expansion valve or capillary tube when the sudden expansion of the refrigerant occurs, due to which its temperature and pressure fall down. The refrigerant leaves the expansion valve or capillary tube in a partially liquid state and partially gaseous state.

Evaporation or Cooling: The partially liquid and partially gaseous refrigerant at a very low temperature enters the evaporator where the substance to be cooled is kept. It is here where the refrigeration effect is produced. The refrigerant absorbs the heat from the substance to be cooled and gets converted into a vapor state. Here are the various process of the Vapor compression cycle (refer to the figure)

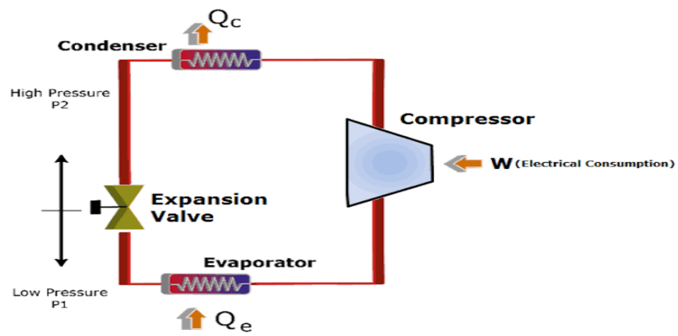
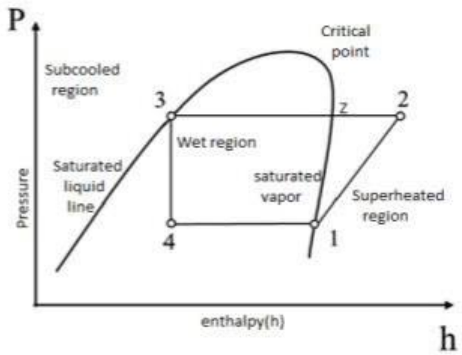


Fig 3.3.1: VCR system



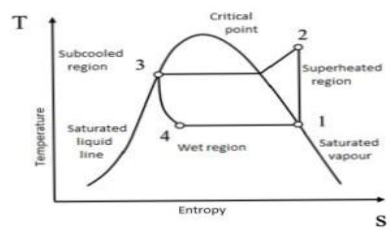


Fig 3.3.2: P-H diagram of VCR system

Fig 3.3.3: T-S diagram of the VCR system

1-2 = Isentropic compression process
2-3=Constant pressure heat rejected
3-4=Isentropic expansion process
4-1=Constant pressure heat absorvation

3.4 LPG Refrigeration Compression Cycle:

Compression: From the LPG gas cylinder, LPG flows through the pipe and reaches the capillary tube. LPG gas pressure is approximate 60 psi. In an LPG cylinder gas is stored at 65 psi. By using a high-pressure regulator LPG is sent to a capillary tube using steel-reinforced high-pressure pipes.

Expansion: At the capillary tube pressure drop takes place from 60 psi to 17.4 psi. For that pressure drop to take place a suitable dimension capillary tube is selected.

Evaporation or Cooling: In the evaporator, LPG is converted into a vapor form with low pressure. After passing through the evaporator low pressure and temperature LPG vapor absorbs heat from the chamber system and the required cooling effect is produced in the evaporator.

Exhaust: After performing the cooling effect low-pressure LPG goes into the burner where the burning takes place.

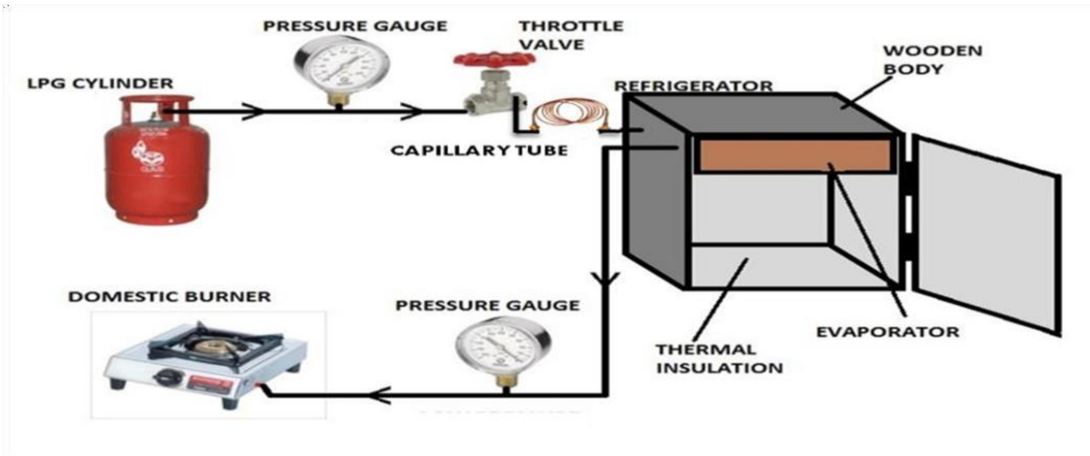


Figure 3.4 Design Model

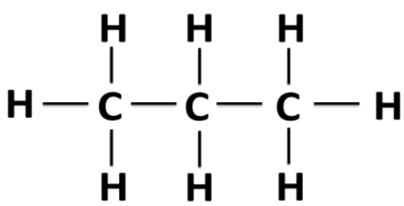
3.5 EQUIPMENT REQUIRED:

3.5.1 LPG CYLINDER:

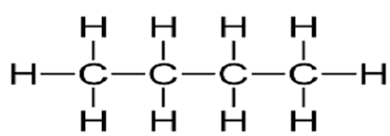
LPG is a mixture of propane (C_3H_8) and butane (C_4H_{10}). Total gas supplies 12kg to 24Kg capacity cylinders for domestic use. By using a suitable regulator LPG is sent into a capillary tube. LPG is used as a fuel for domestic, industrial, horticultural, agricultural, cooking, heating, and drying processes. LPG can be used as 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.

Propane (C_3H_8) : CH_3-CH_2-CH_3

Butane (C_4H_{10}): CH_3-CH_2-CH_2-CH_3



Propane (C_3H_8)



$C_3H_8 + 5O_2 = 3CO_2 + 4H_2O$

$C_4H_{10} + 13\backslash 2O_2 = 4CO_2 + 5H_2O$

Name	Propane (C_3H_8)	Butane(C_4H_{10})
Boiling Point	-42^0C	-1^0C
Freezing Point	-188^0C	-138^0 C
Specific Volume	59.03 psi	16.3 psi

3.5.2 EVAPORATOR:

An evaporator is an important component together with other major components in a refrigeration system such as a compressor, condenser, and expansion device. The reason for refrigeration is to remove heat from the air, water, or other substance.

It is here that the liquid refrigerant is expanded and evaporated. It acts as a heat exchanger that transfers heat from the substance being cooled to a boiling temperature

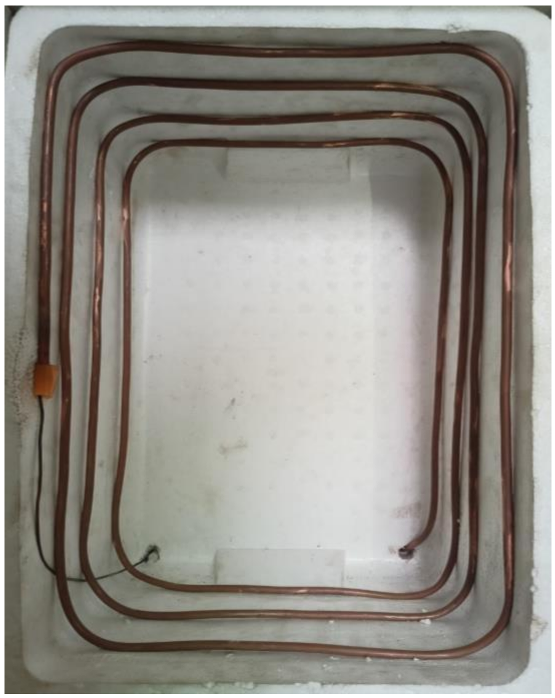


Fig:3.5.2- Evaporator

3.5.3 Capillary Tube:

The capillary tube is one of the most commonly used throttling devices in refrigeration and air conditioning systems. The capillary tube is a copper tube with a very small internal diameter. It is very long and it is coiled to several turns so that it would occupy less space. The internal diameter of the capillary tube used for refrigeration applications varies from 0.5 to 2.28 mm (0.020 to 0.09 inches). The capillary tube is shown in the picture. The decrease in pressure of the refrigerant through the capillary depends on the diameter of the capillary and the length of the capillary.

Smaller is the diameter and more is the length of the capillary more is the drop-in pressure of the refrigerant as it passes through the capillary tube.

Fig:3.5.3- Capillary tube

3.5.4 PRESSURE GAUGES:

A pressure gauge is a method of measuring fluid, gas, water, or steam intensity in a pressure-powered machine to ensure there are no leaks or pressure changes that would affect the performance of the system. Pressure systems are designed to operate within a specific pressure range. Any deviation from the acceptable norms can seriously affect the workings of the system.

Pressure gauges have been used for more than a hundred years and have been constantly evolving to fit the needs of new applications. The implementation and use of pressure gauges have made them a necessity as more and more pressure systems become operational

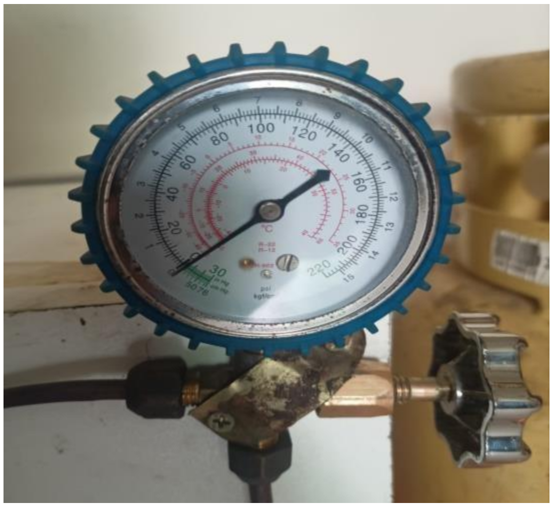


Fig:3.5.4- Pressure Gauge

3.5.5 High-Pressure Pipes:

Pressure piping is a set of pipes that are used **to contain fluid at high pressure**. High-pressure gases were transported through pressure piping. High-pressure vapor should be carried through pressure-piping to a storage bank. Pressure piping is a set of pipes that are used to contain fluid at high pressure.

Fig: 3.5.5-High Pressure Pipe

3.5.6 High-Pressure Regulator:

High-pressure regulators regulate the output pressure from 1 psi to as high as 60 psi. There are several different high-pressure regulators available. Some high-pressure regulators are "preset". That is, the propane pressure is fixed at a certain pressure; i.e., 10 psi or 20 psi.

Fig:3.5.6- High Pressure Regulator

3.5.7 Temperature Meter:

A temperature meter is an instrument used to measure the temperature of beings or things. We can easily measure our LPG Refrigerator's internal and external temperature on the Digital temperature meter.

Fig: 3.5.7- Temperature Meter

3.5.8 Gas stove:

LPG is a clean fuel (comparable with biogas); it releases less pollutants than any other fuel except electricity. LPG stoves are easy to light. LPG stoves quickly supply heat and work more efficient than stoves which burn biomass. On LPG stoves cooking is fast. Simple and precise heat regulation.

Fig:3.5.8 Gas Stove

3.6 Working Procedure:

The LPG refrigerator is shown in the figure 3.9. We make one box of the Thermo-coal sheet. The thermo-coal sheet size is 10mm used for the LPG refrigerator. The size of the evaporator is 295*435*230 mm^3. We kept the thermo-coal sheet because the cold air cannot transfer from the inside to the outside of the refrigerator. And the evaporator is wrapped totally with a wood sheet. The schematic diagram of the LPG refrigeration system is shown below diagram 3.9. The gas cylinder is connected to a high-pressure regulator, which is connected to high-pressure pipes. To the other end of the high-pressure pipes, the 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 the evaporator. The evaporator coil end is connected to the stove by another high-pressure pipe. One pressure gauge is put between the capillary tube and cylinder and another is put at the end of the evaporator.

Fig:3.6 Construction Diagram

The basic idea behind the LPG refrigerator is to use the LPG to absorb heat. The simple mechanism of the LPG refrigeration working is shown in figure 3.9

1. LPG is stored in an LPG cylinder at high pressure. When the valve of the regulator opens, gas starts flowing through the pipe. Then this gas enters the capillary tube.

2. When this high-pressure LPG gas enters the capillary tube its pressure drops and consequently its temperature also decreases but during this process the enthalpy of the LPG gas remains the same.

3. After the capillary tube LPG gas enters the evaporator. In the evaporator, this low-pressure and low-temperature gas absorb heat from the surrounding. Thus we get the cooling effect.

4. After the cooling effect is produced, then enters into the burning section where this low-pressure gas is ready to get burned.

CHAPTER: 4

RESULT AND DISCUSSION

4.1 Important Term: The coefficient of performance, COP, of a refrigerator is defined as the heat removed from the cold reservoir Qcold (i.e., inside a refrigerator) divided by the work W done to remove the heat (i.e., the work done by the compressor.)

$$COP \frac{Qcold}{W} = \frac{Qcold}{Qhot - Qcold}$$

Since the first law of thermodynamics must be valid also in this case (Q_{cold} + W = Q_{hot}), rewrite.

$$COP \frac{Qcold}{W} = \frac{Qcoid}{Qhot - Qcold}$$

We can write also,

$$COP = \frac{T_{cold}}{T_{hot} - T_{cold}}$$

Where,

COP= Co-efficient of Performance

Q_{cold} = Evaporator Heat

Q_{hot}= Ambient Heat

W = Work Done of Refrigerator

T_{cold} = Evaporator Temperature

T_{hot} = Ambient Temperature

From the LPG gas cylinder of 12 kg, LPG flows through the pipe and reaches to the capillary tube. LPG gas pressure is approximate 60 psi.

Let's try to find out the actual data of LPG refrigerator:

The experiment of this project was done on 5 September, 2022 at 1:00 p.m. and readings were taken at 10 minute's interval, for 1 hour which is as shown in table 1 below:

Time (Min)	Inlet Pressure (PSI)	Outlet Pressure (PSI)	Ambient Temp (^{0}c)	Evaporator Temp (^{0}c)
10	50.00	18	31	31
20	45.00	13	31	25.8
30	42.5	12	31	22.8
40	41.00	10	31	19.8
50	39	10	31	19
60	37.5	14	31	18

Table 4.1 , Data chart.

4.2 Calculation:

From above table, we find out the data

Here,

T_{hot}=31 °C

T_{cold}= 18 °C

m= 12 kg/h

C_p =1.68 kj/kgK

We Know,

$$COP = \frac{T_{hot}}{T_{hot} - T_{cold}}$$

$$COP = \frac{18.00}{31.00-19.00}$$

COP=1.38

When

T_{hot}=31 °C

T_{cold}= 19 °C

COP = 1.58

When

T_{hot}=31 °C

T_{cold}= 19.8 °C

COP = 1.76

When

T_{hot}=31 °C

T_{cold}= 22.8 °C

COP = 2.78

When

T_{hot}=31 °C

T_{cold}= 25.8 °C

COP = 4.96

The capacity of LPG refrigeration

When

T_{hot}=31 °C

T_{cold}= 18 °C

$Q=m\times C_p\times \Delta T$

$=\frac{12}{3600}\times 1.68\times(304-291)$

=0.0728

Work done of LPG refrigeration

$W=\frac{Q}{COP}$

$=\frac{0.072}{1.58}$

=0.046 KW

Now,

$$Q = (31\text{-}18)\times12\times1.68 \text{ Kw}$$
$$= 262.08$$
$$= 74.88 \text{ TR}$$

Graph :

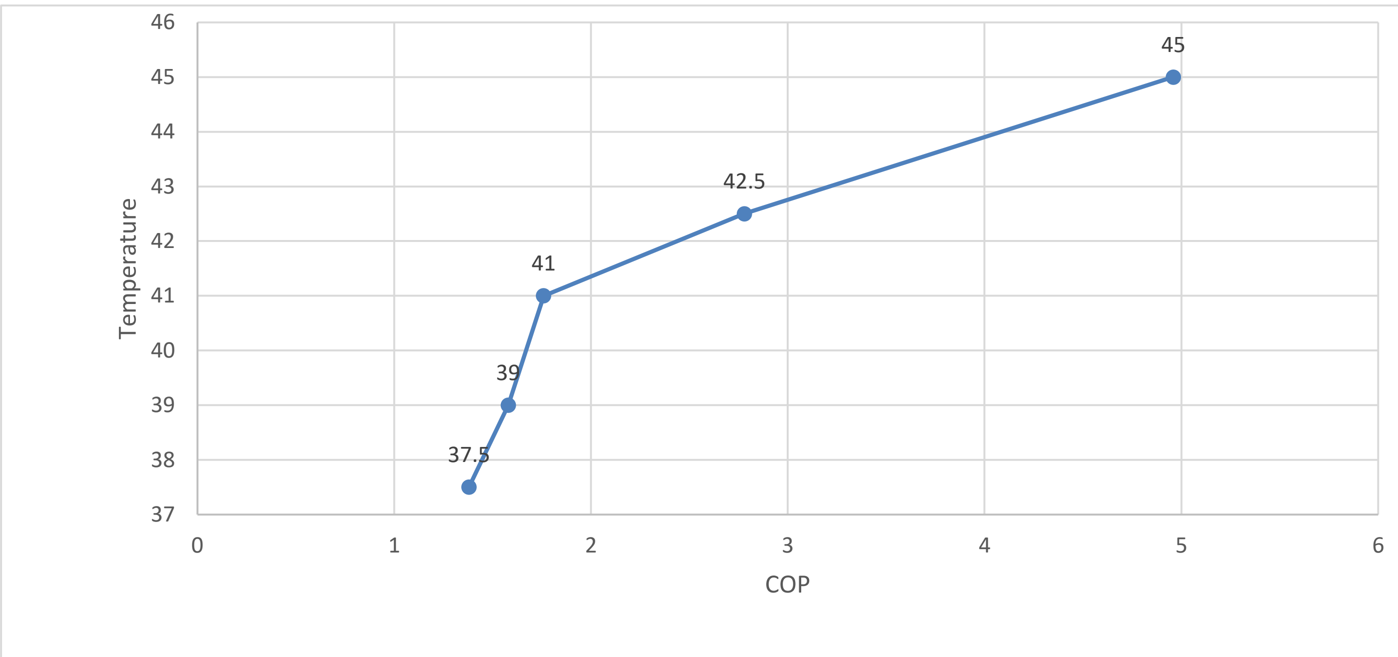


Fig : 4.2.1: cop vs temperature

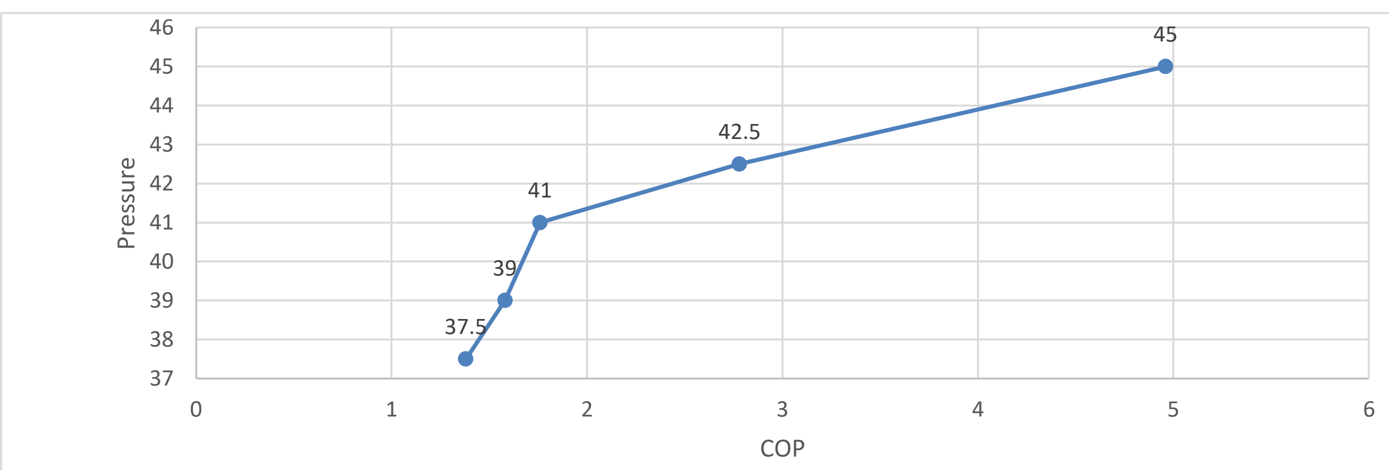


Fig 4.2.2 : cop vs pressure

4.3 Result:

The performance of the refrigerating system was evaluated by analyzing COP of the system .The refrigerating effect produce and work input to the developed system were used to find out the COP of the system .

The COP of a domestic refrigerator is normally up to 2.95 Over a full day , a domestic refrigerator power consumption is typically recorded between 1 to 2 kilowatt -hour (kwh) but an LPG refrigerator consumes no electricity So if we used an LPG refrigerator ,we can eliminate the electricity cost . .

CHAPTER: 05

5.1 Conclusion:

It is concluded that refrigerating effect is produced with the use of LPG. From the observation table, It is concluded that, the evaporator temperature downs from 33 Cto 18 in 60 minutes. It is also concluded that in the capillary tube pressure of gas 60 psi from the cylinder is reduced to 17.4 bar. The capillary tube is more suitable in LPG refrigeration systems It does not require an external source to run the system and the moving part is absent in the system. Henceforth, maintenance cost is less as well as less silent operation. This system is cheaper in initial as well as running costs. It does not require an external energy source to run the system and no moving part in the system so maintenance is also very low. We also conclude that, we try the burnt to the exhaust LPG, the pressure of exhaust gas is less than 1 psi, and the small flame is produced by the burner. LPG will not harm the environment and the ecosystem. The potential for ozone layer depletion and global warming will be reduced due to the usage of current refrigerants in domestic refrigerators. This system is most suitable for hotels, industries, refineries, and chemical industries where consumption of LPG is very high

We can see that COP of a domestic refrigerator is normally up to 2.95. More moving parts in the domestic refrigerator and not eco-friendly. A domestic refrigerator requires more maintenance and operation is noisy. But the LPG refrigerator run without electricity by eliminating the compressor and condenser. the LPG Refrigerator COP is 1.3. which is lower than a domestic refrigerator. So LPG Refrigerator is an eco-friendly refrigerator and it does not harm ozone depletion.

5.2 Future Scope:

The system can further be improved and implemented in the air conditioning of vehicles where LPG is used as fuel. The project can be implemented in restaurant and community program hall, mobile canteen, mind id-day meal of school so to preserve food products like vegetables, milk, etc.

5.3 Reference:

1. Dr. Amir S.Dawood &Salim Ibrahim Hasan, "Numerical study of Refrigerant flow in capillary tube using Refrigerant(R134a), Journal (2011) 1- 19

2. Zainalzakaria & Zuliaikhashahrum, "The possibility of using LPG in Domestic Refrigeration System"(2011) 347-354.

3 A Textbook of Refrigeration And Air Conditioning By R.S. Khurmi, S. Chand Publication.

4. Bilal, A.A. And Salem, A.A. (2002). Assessment of LPG as a possible Alternative to R12 in Domestic Refrigerators. Ener.Conv. and Man. 44: 381-388. Fatouh, M. and Kafafy, M.E (2005). Experimental Evaluation of a Domestic Refrigerator Working with LPG. 26: 1593-1603.

5. A Study Paper on LPG as an Alternative Refrigerant for Refrigeration -Deokate S.M, Pingale A.T, Satpute A.K, Deshmukh A.M, Uzagare N.A