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Performance Analysis of LPG Refrigeration System

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ABSTRACT: In this project we have designed and analysed a refrigerator using LPG as refrigerant. The pressure of LPG is high and this pressurised LPG is passed through the capillary tube of small internal diameter, the pressure of LPG is decreased due to expansion and phase change of LPG occurs. Due to phase change from liquid to gas latent heat of evaporation is gained and the temperature is decreased. In this way LPG can produce refrigerating effect in the surrounding. From experimental investigations, we have found that the COP of an LPG Refrigerator is higher than a domestic refrigerator.

KEYWORDS: Liquefied Petroleum Gas, Coefficient of Performance, Capillary Tube, Evaporator, Environment.

I. 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. LPG is stored in liquefied state in cylinder before its utilization as fuel. According to the energy survey, the refrigerator is one of the heaviest power consumers amongst household appliances. The energy consumption of refrigerators has improved steadily year over year.

It works on the principle that the expansion of LPG will be takes place during the conversion of liquid LPG into gaseous form. As a result of this, LPG gas pressure drops, and the volume of gas will be increase this will be result into dropped in temperature of gas and it acts as refrigerant. According to second law of thermodynamics, this process of cooling can only be performed with the aid of some external work. Hence, the power supply is regularly required to drive a refrigerator.

The substance which works in a refrigerator to extract heat from a cold body and to deliver it to a hot body i.e., to surrounding is called refrigerant. Globally 17500 metric tons of conventional refrigerants is consumed by domestic refrigeration like CFC, HFC which causes high depletion if ozone layer (ODP) and Global Warming Potential (GWP).

The use of LPG instead of CFC 22 has made a better progress since it has an environment friendly orientation with no ODP. Good product efficiency is resulted using LPG because of its characteristics. Thus, we must examine these two types of refrigerants (LPG and CFC 22) in a modified domestic refrigerator comparing their performance characteristics parameters like pressure, temperature etc. in refrigerator and considering safety while conducting the

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practical experiment. It indicates LPG can be used as an alternative refrigerant to CFC 22 after performing the test on new system.

II. SCOPE OF WORK

To study and analyse the Vapour Compression Refrigeration system is our basic objective. We are substituting the compressor and condenser by an LPG cylinder. The pressure energy of LPG is very high as it can be compressed up to 12.5 bars and hence this pressure energy of LPG can be used for refrigeration by usage of this LPG system is also very low.

III. EXPERIMENTAL SETUP

WORKING PRINCIPLE OF VAPOUR COMPRESSION REFRIGERATION SYSTEM

The LPG Refrigerator is work on the simple Vapour Compression Refrigeration system. The construction and working of simple VCERS is as shown in fig. 1.

Process 2-3: When the compressor is started, it draws the low-pressure vapour from the evaporator at state 2 and compresses it is entropically to a sufficiently to a high pressure up to state 3. Since the compression work is done on the vapour, its temp also increases.

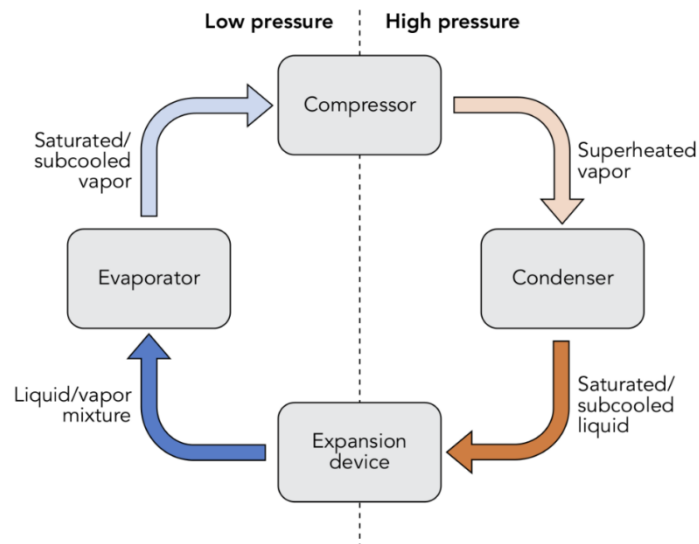


Fig-1: Schematic diagram of simple VCERS

Process 3-4: Hot vapour from compressor under pressure is discharged into the condenser where condenser cooling medium usually water or surrounding air is absorbing 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.

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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.

LPG REFRIGERATION CYCLE EXPLANATION

The simple mechanism of the LPG refrigeration working is shown in fig. 2.

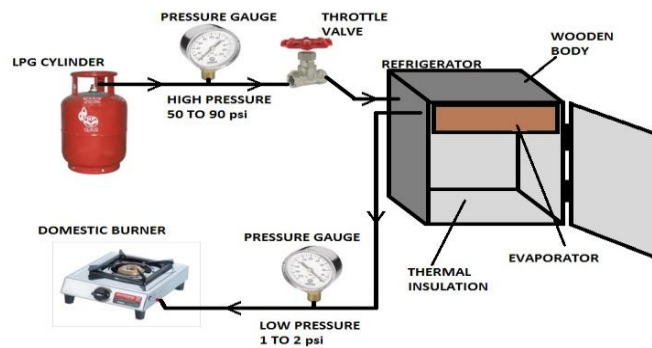


Fig. 2. Simple mechanism of the LPG refrigeration system

The idea behind LPG refrigeration is to absorb heat from surrounding by using the evaporation of an LPG. The pressure of LPG which is stored in cylinder is at about 80psi. 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 is goes in the capillary tube from high pressure pipe. In the capillary tube this high-pressure LPG 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 vapour form which absorbs the heat from the cooling chamber. Thus, the cooling chamber becomes cools down.

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.

COMPONENTS FEATURES GAS CYLINDER

From gas cylinder LPG in the start at a pressure of approximately 5.156 flows through the pipe to reach the capillary tube.



Fig. 3. LPG Gas Cylinder

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CAPILLARY TUBE

A capillary tube is of copper having a small-bore diameter. It reduces the pressure of liquid refrigerant from condenser pressure to evaporator pressure when connected to a liquid line. The length of capillary tube is greater when the evaporator pressure is lower. The capillary tube is a simple device with no moving part. However, its small bore makes it necessary that a filter and drier is fitted before the capillary tube to prevent choking. While passing through capillary tube the LPG expands and its pressure drops less than 1.2 bar.



Fig. 4. Capillary Tube

EVAPORATOR

In evaporator LPG is converted into the vapor form with low pressure. The evaporator is also an important component of the refrigeration system. The cooling effect is produced by passing the refrigerant through evaporator coil.



Fig. 5. Evaporator

PRESSURE GAUGE

The most used mechanical gauge is Bourdon type 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 pressure which is the difference between fluid pressure and outside atmospheric pressure. These gauges are available in the different ranges of pressure.

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Fig. 6. Pressure gauge

GAS BURNER

After performing the cooling effect, low pressure LPG gas goes into the burner where it burns and through generator to generate electricity.



Fig. 7. Gas Burner

OPERATIONAL PARAMETERS

Initial temperature of water at the time of experiment: 31°C

Initial temperature of evaporator at the time of experiment: 29.5°C

Table: Observation Table

Time (min)	Inlet Pressure (bar)	Outlet Pressure (bar)	Water Temp. (°C)	Evaporator Temp. (°C)
15	5.525	1.22	30.9	28
30	5.525	1.22	27.4	26.6
45	5.525	1.22	26	24
60	5.525	1.22	24.4	22.4
75	5.525	1.22	22.8	20
90	5.525	1.22	21	18

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CHARTS

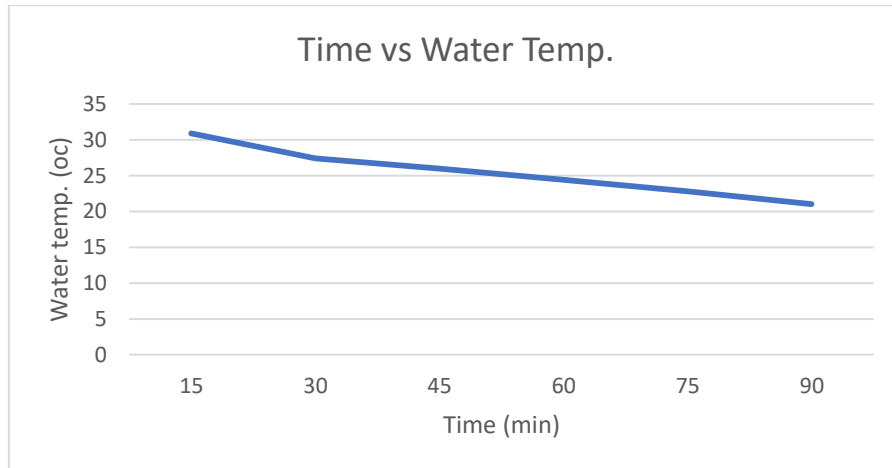


Chart 1: Time vs Water Temp

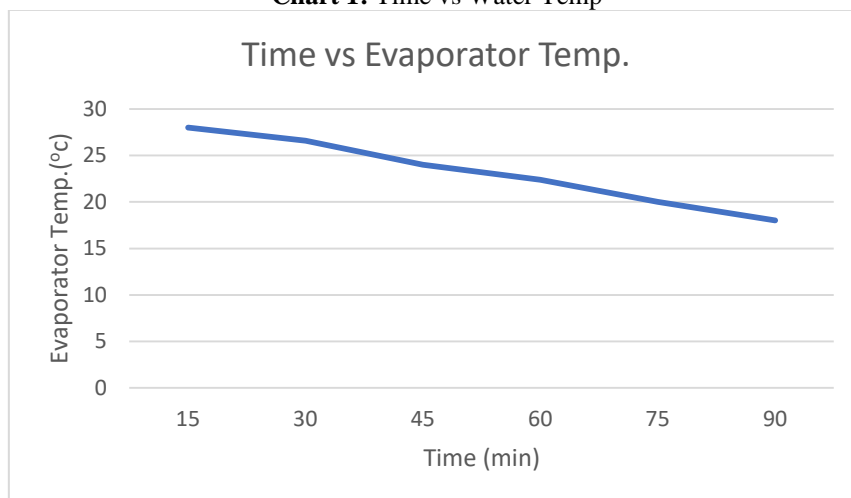


Chart 2: Time vs Evap. Temp

REFRIGERATING EFFECT

The properties of LPG at 5.525 bars are

Enthalpy $h_1 = 430.3$ kJ/Kg

The properties of LPG at 1.22 bars are

Enthalpy $h_f = 107.3$ kJ/Kg

Temp. $t_{sat} = -30$ °C

Heat extracted from evaporator in 1.5 hour

$(Q_{eva}) =$ Heat absorbed by LPG (Q_{LPG})

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

$m_w =$ mass of water = 1kg

$c_{pw} =$ specific heat of water = 4180J/kgK

$(\Delta T)_w = 10$ °C

$X_{LPG} =$ Dryness fraction of LPG from graph = 0.5

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

$$= m_w c_{pw}(\Delta T) + m_a c_{pa}(\Delta T) + Q_L$$

We have taken 1 kg of water in bottle. Since there is very less amount of air so it is neglected.

$$= 1 \times 4180 \times 10 = 41800 \text{ J}$$

Heat absorbed by LPG (Q_{LPG}) = Latent heat absorbed (Q_L)_{LPG} + Sensible heat gain (Q_{Sen})_{LPG}

We have the volume flow rate of LPG is 0.1 litre per min. and the specific volume of LPG at 1.22 bar pressure is $1.763 \times 10^{-3} \text{ m}^3/\text{Kg}$.

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

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

$$m = 9.448 \times 10^{-4} \text{ Kg/sec}$$

$$= m_{LPG} \cdot x_{LPG} \cdot h_{fg} + m_{LPG} \cdot c_{pLPG} \cdot (T_{sup} - T_{sat})$$

$$= 9.448 \times 10^{-4} \times 0.5 \times 375 \times 103 \times 5400 + 9.448 \times 10^{-4} \times 1.67 \times 48$$

$$= 0.956812 \text{ MJ/hr.}$$

$$h_2 = h_f + X \cdot h_{fg}$$

$$= 107.3 + 0.5 \times 375$$

$$= 294.8 \text{ KJ/Kg}$$

$$h_g = h_f + h_{fg}$$

$$= 107.3 + 375 = 482.3 \text{ KJ/Kg.}$$

$$h_3 = h_g + C_p \cdot \Delta T$$

$$= 482.3 + 1.67 \times 48$$

$$= 562.46 \text{ KJ/Kg}$$

So, the refrigerating effect is,

$$RE = h_3 - h_2$$

$$= 562.46 - 294.8$$

$$= 267.66 \text{ KJ/Kg}$$

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.

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

$$= 3.1354/14.5$$

$$= 0.2162 \text{ kWh}$$

We run the setup for 1.5 hr. for that power is

$$= 0.2162 \times 1000 / (9.45/10000) \times 5400$$

$$= 42.39 \text{ W}$$

COP of the LPG Refrigeration System

$$\text{COP} = (h_3 - h_2) / W$$

$$= 267.66 / 42.39$$

$$= 6.3$$

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 to atm. $Q_L = m \times C_v$ the volume flow rate of LPG is 0.1 liter per min. and the specific volume of LPG at 1.525 bar pressure is $1.763 \times 10^{-3} \text{ m}^3/\text{Kg}$.

Therefore, mass flow rate of LPG is

$$= 0.0001/1.763 \times 10^{-3}$$

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

$$m = 9.448 \times 10^{-4} \text{ Kg/sec}$$

$$C_v = 46.1 \text{ MJ/Kg}$$

$$Q_L = 9.448 \times 10^{-4} \times 46.1 \times 103$$

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= 43.56 W

Hence, from this we have got the refrigerating effect from the system as well as heat from the LPG.

IV. COMPARISON WITH DOMESTIC REFRIGERATOR

Cop of a domestic refrigerator is normally up to 2.95 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.

The COP of the refrigerator is $COPR = 2.95$

V. 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.

VI. CONCLUSIONS

The aim of this paper is to use LPG as a refrigerant and utilizing the energy of the high pressure in the cylinder for producing the refrigerating effect and then for running the generator or burner. This paper concluded that the COP of LPG refrigerator(6.3) is greater than COP of domestic refrigerator(2.95) using conventional refrigerants and is shown diagrammatically. This system has low initial as well as running cost. It does not require any external energy sources to run the system and no moving part, so maintenance is also very low. In this paper the refrigeration is amplified remarkably, and a cheaper and eco-friendly method is developed. This system is most suitable for hotel, industries, refinery, chemical industries where consumption of LPG is very high.

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