PERFORMANCE AND EVALUATION OF REFRIGERATION SYSTEM USING LPG

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***Abstract*:** In this project we have designed and analyzed a refrigerator using LPG as refrigerant. As the pressure of LPG is high this stored in the cylinder. As this pressurized 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 in an isenthalpic process. Due to phase change from liquid to gas latent heat of evaporation is gained by the liquid refrigerant and the temperature decreased. By this way LPG can produce refrigerating effect in the surrounding. From experimental investigations, we have found that the COP of a LPG Refrigerator is higher than a domestic refrigerator. 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 refrigeration effect in certain time. The refrigerator worked efficiently when the LPG was used as a refrigerant instead of R134a. The evaporator temperature reached 5^{o}C with an ambient temperature of 35^{o}C. From the experiment which is done in the 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, Vapor Compression Refrigeration system, Refrigerating Effect, COP.

1. INTRODUCTION

The term 'refrigeration' is used for the process of removing heat (i.e. Cooling) from a substance. This 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. LPG is changed and converted from liquid to gas state and then it passes through the evaporator where it absorbs the heat and produces the refrigerating effect. 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, we suggest COST FREE Cooling Systems. Although government agencies are not able to supply continuously 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 electricity. Thus we have to 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 practical experiment.

OBJECTIVES

The main objectives of this project "LPG Refrigerator" are as follows:

1) This project work investigates the result of an experimental study carried out to determine the performance of domestic refrigerator when a propane-butane mixture, which is liquefied petroleum gas (LPG).

2) To identify the form of residual waste in traditional refrigeration system.

3) Compare the important characteristics between LPG refrigeration system and traditional refrigeration system.

4) The performance is to be compared between the existing refrigerator and LPG refrigerator.

SCOPE OF WORK

To study and analyze the Vapour Compression Refrigeration system is our basic objective. We are substituting the compressor and condenser by a LPG cylinder. The pressure energy of LPG is very high so that 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.

1. EXPERIMENTAL SETUP

Working Principle

The LPG Refrigerator is work on the simple Vapour Compression Refrigeration system. The construction and working of simple VCRS 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 temperature also increases.

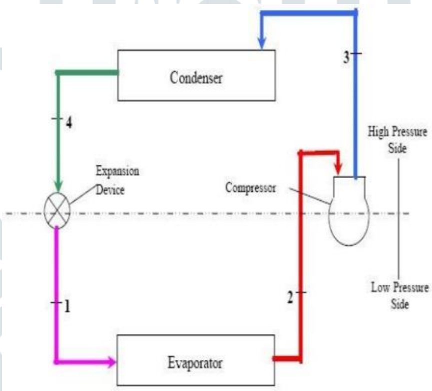

Fig-1: Schematic diagram of simple VCRs

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 absorb 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.

Actual System Setup

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

The idea behind 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 lowering this pressure of LPG up to pressure 15 psi by using capillary and so that cooling is done on surrounding by absorbing heat is entropically. 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 in to 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.

Fig.-2: Actual Setup of LPG Refrigerator

Fig.-3: Actual Setup of LPG Refrigerator

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.

CONSTRUCTION COMPONENTS

1. **LPG Gas Cylinder and Burner:**

Fig 4: LPG Gas Cylinder

Fig5: Burner

Liquefied Petroleum Gas is combination of Propane (C3H8) and Butane (C4H10). LPG is used as a fuel for domestic purpose, drying, and industrial purpose. LPG is also used for cooking, heating fuel in Domestic Burner for burning purpose. It is also used in agriculture and in various machineries.

LPG is general composition of two gases mainly Propane (C3H8) and Butane (C4H10), either stored separately or together as a mixture in a cylinder. These gases can be liquefied at a normal temperature by application of a pressure increases. LPG is stored in a cylinder at about 12.5 bars.

2. Capillary Tube

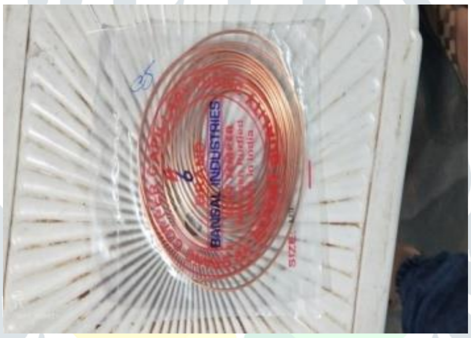

Fig6: Capillary Tube

Capillary tube is a copper tube of very small internal diameter and it is of long length, commonly of 2.28 to 3.0m length. Internal diameter tube may varies from 0.5 (0.020 to 0.09 inch).lpg refrigerant enters through the capillary tube; its pressure drops down suddenly due to its small diameter.

3. Evaporator

Fig7: Evaporator

It's the evaporators where the actual cooling effect takes place in the refrigeration systems. 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 cabin.

4. Pressure Gauges

Fig8: Pressure Gauges

Instruments that are used to measure pressure are called pressure gauges or vacuum gauges. These gauges are available in63mm, 100mm, and 150mm sizes and can be customized as per client. A Bourdon gauge uses a coiled tube, when it expands due to pressure increases cases and a rotation of an arm connected to the tube takes place.

5. Digital Temperature Probe

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Fig9: Temperature Sensor

A digital temperature probe is a device that provides temperature measurement through an electrical signal.

6. ON/OFF Valve

Fig10: Flow control value

A flow control valve is used to control the flow or pressure of a fluid. High Pressure Pipes When there is a need of transferring gas at high pressure, the range of high pressure pipes are used. It consists of a steel pipe with steel spheres fixed at both the terminals. These spheres are pressed against the seating of connecting hole with the help of two swiveling nipple and thus the gas leakage is prevented.

3. EXPERIMENTAL ANALYSIS

1. Copper Tubes: According to the pressure 100 psi the outside diameter of tube = 7 mm and the thickness of the tube is = 1.5 mm.
2. Capillary tube: By considering the pressure and flow rate we select the capillary tube with internal diameter 2.28m and length 3.0m.
3. Evaporator: We select the evaporator of standard size of domestic refrigerator which is plate and tube type evaporator.
The evaporator has following dimensions: Length = 325 mm, Breadth = 265 mm and Height = 135 mm
The evaporator is made from six plywood sheets of 8 mm thickness which enclose six glass wool sheets of 12 mm thickness so as to prevent heat transfer.

Operational Parameters

- **Size of refrigerator =** Height x Width x Breadth
- **Size of Evaporator =** Height x Width x Breadth

= 325 X 265 X 135

Capillary tube = Mini tube =0.031m

Medium tube = 1m

Max tube=2m

Pressure gauges =Size – 63mm

Pressure- 250psi

Temperature sensors = Min Temp: -40F

Max Temp: 500F

On/off valve = Type – Class 150

Pressure-150 Psi
2. Initial temperature of water at the time of experiment : 31^{O}C

3. Initial temperature of evaporator at the time of experiment : 29.5^{O}C

Table-1: Observation Table

Time (min)	Inlet Pressure (bar)	Outlet Pressure (bar)	Water temp. (^{O}C)	Evapo. Temp. (^{O}C)
15	5.525	1.22	30.9	28
30	5.525	1.22	27.4	26
40	5.525	1.22	26	24
60	5.525	1.22	24.4	22’
75	5.525	1.22	22.8	20
90	5.525	1.22	21	18

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 ^{0}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/kg.K $(\Delta T)_W$ =10^{O}C
X_{LPG} = Dryness fraction of LPG from graph =0.5 (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.
= 1×4180×10
= 41800 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 liter per
min. and the specific volume of LPG at 1.22 bar pressure is 1.763×10-3 m^3/Kg.
Therefore mass flow rate of LPG is = 0.0001/1.763×10-3
= 0.0567 Kg/min
m = 9.448×10^{-4} Kg/sec
= m_{LPG} .x_{LPG} .h_{fg} + m_{LPG} .c_{pLPG} . (T_{sup}-T_{sat})
=9.448×10^{-4}×0.5×375×103×5400+
9.448×10^{-4}×1.67×(48)
= 0.956812 MJ/Hr.

h_2 = h_f+X.h_{fg}
= 107.3 + 0.5 x 375
= 294.8 KJ/Kg

h_g = h_f+ h_{fg}
= 107.3 + 375
= 482.3 KJ/Kg.

h_3 = h_g + C_p. ΔT
= 482.3 + 1.67 x 48
= 562.46 KJ/Kg
So the refrigerating effect is, RE = h_3 – h_2
= 562.46 – 294.8
= 267.66 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 kWh
We run the setup for 1.5 hr. for that power is
= 0.2162×1000/ (9.45/10000) ×5400
= 42.39W

COP of the LPG Refrigeration System

COP = (h3-h2)/W
= 267.66/42.39
= 7.3 to 8
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. QL= m×Cv
The volume flow rate of LPG is 0.1 liter per min. and the specific volume of LPG at 1.525 bar pressure is 1.763×10-3 m3/Kg.
Therefore mass flow rate of LPG is
= 0.0001/1.763×10-3
= 0.0567 Kg/min
m = 9.448×10^{-4} Kg/sec Cv = 46.1 MJ/Kg
QL= $9.448\times10^{-4}\times 46.1\times103$
= 43.56 W
Hence, from this we have got the refrigerating effect from the system as well as heat from the LPG.

4. COMPARE 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.

5. 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.

6. CONCLUSIONS

The refrigerating effect was calculated by us by varying the LPG properties like (pressure, temperature and enthalpy) to and fro the evaporator using a high pressure regulator and the quantity of refrigerating effect we get is 267.66 KJ/kg. We cannot predict the quantity of energy that might be used up in filling of 1 kg LPG in the refinery and no data available in any energy audit report of refinery, so we have considered the input energy from the refilling plant only.
We get slow rate of refrigerating effect because of leakages present in the system. This can be improved by using precise manufacturing techniques and methods.
For input energy we have taken the amount of energy required to refill 1 kg of LPG through the bottle filling plant which is 0.216 kWh. The input energy for different plant might be different. If we give an energy input in this way we get the COP of the LPG refrigerator 6.3 and which is again higher than the domestic refrigerator. There also might be a change in future scope if the energy input for 1kg of LPG filling would be taken from any of the refinery energy audit report.
In a LPG refrigeration system capillary tube is more adjustable and better device. The initial and running cost of this LPG refrigeration system is really less. No outside energy source is required to run the system. As well as no moving components are present in the system which further reduces the maintenance cost as well. This LPG refrigeration system has wide scale application in hotel industries, chemical industries where the LPG consumption is at a higher level.

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