Design Analysis and Performance of Low Cost Refrigeration System using LPG

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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. In this project we have designed and analyzed a refrigerator using LPG as refrigerant. As the pressure of LPG is high this stored in 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. In 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.

Key Words: LPG Refrigeration, Capillary tube, Evaporator, COP, Vapor Compression Refrigeration system, Refrigerating Effect.

1. 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. 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. 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 by the use of LPG because of its characteristics. It indicates LPG can be used as an alternative refrigerant to CFC 22 after performing the test on new system.

2. OBJECTIVES:
The Objectives of this project “Performance evolution of Domestic Refrigerator using LPG Cylinder” are as follows:

• To identify the form of residual waste in traditional refrigeration system.
• To identify the form of residual waste in traditional refrigeration system.
• To distinguish between the current existing refrigerator cost and estimated cost of LPG refrigerator.

3. SCOPE OF WORK:

• It can be useful in remote parts where electricity is not available.
• It can play an important role in restaurants where continuously cooling and heating is required.
• It can be used in automobiles running on LPG or other Gaseous fuels for air conditioning.

4. EXPERIMENTAL FEATURE:

4.1 WORKING PRINCIPLE:
The LPG Refrigerator uses evaporation of LPG to absorb heat. LPG is stored in cylinders at pressure at about 80 psi. We lowering this pressure to pressure of 1 psi so that the heat absorbed adiabatically from refrigeration box and cooling is obtained on surrounding. LPG is stored in the LPG cylinder under high pressure. When the gas tank of regulators is opened then high pressure LPG passes in gas pipe. This LPG passed to capillary tube at high pressure. High pressure LPG is converted in low pressure at capillary tube with enthalpy remains constant. Low pressure LPG is passed through evaporator. LPG is converted into low pressure and temperature vapour from passing through the evaporator which absorbs heat from the refrigeration box. Thus the refrigeration box becomes cools down. Thus we can achieve cooling effect in refrigerator. LPG from evaporator is then passed through pipe to the burner.
5. CONSTRUCTIONAL FEATURES:

A. LPG GAS CYLINDER:
LPG is Liquefied Petroleum Gas which contains mainly Propane (C₃H₈) and Butane (C₄H₁₀). These two either stored separately or together as a mix. LPG can be used as a fuel for domestic, industrial, agricultural, cooking, heating and drying processes. It can also be used as an automotive fuel or as propellant for aerosol.

The LPG is stored in the cylinder at about 12.5 bars. The use of LPG Cylinder eliminates the compressor and condenser from the system.

B. Evaporator:
The evaporator is also an important component of the refrigeration system. The cooling effect is produced by passing the refrigerant through evaporator coil. The cooling effect is produced by passing the refrigerant through evaporator coil. The evaporator removes heat from the substance and transfers it to the refrigerant. It means the evaporator acts as a heat exchanger. The freezer is the evaporators as the water freezes into ice in this compartment. The refrigerant is passed through the capillary tube at very low temperature and pressure to the evaporators. The heat is absorbed by this refrigerant from the substance that is to be cooled and thus the refrigerant gets heated while the substance is cooled.

C. CAPILLARY TUBE:
Capillary tubes are tubes with small internal diameter. This diameter varies from 0.5 to 2.28 mm. Commonly used capillary tubes are made up of copper. When the refrigerant enters in the capillary tube, due to very small diameter its pressure drops down suddenly. The decrease in pressure of the refrigerant through the capillary depends on the diameter of the capillary tube and the length of the capillary tube.

D. Pressure Gauge:
This is an instrument used to measure pressure of the gas. There are two types of gauge use in this project viz. high pressure gauge and low pressure gauge.

E. HIGH PRESSURE PIPES:
The high pressure pipes are needed to be used as the LPG is delivered from cylinder at very high pressure. 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.
High pressure pipes are used to transfer high pressure gas from cylinder to capillary tube. These pipes are tested to 100Mp over recommended working pressure.

6. EXPERIMENTAL ANALYSIS

6.1 Specifications of Components:
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 0.78mm and length 2.95m.
3. Evaporator: We have used same evaporator which is used in domestic refrigerator i.e. Plate and tube type evaporator. The evaporator has following dimensions: Length = 330mm, Breadth =270 mm and Height = 140 mm.
4. Refrigerator: Size of Refrigerator box: 325 X 265 X 135

7. ADVANTAGES:

1. There is no any noise or vibration as the system does not contain any moving part.
2. One energy source is utilized for refrigeration and burning processes, Hence energy saving system.
3. It can use waste heat for operation.
4. No electricity is required, so power saving system.

8. OPERATIONAL PARAMETERS:

The experiment of this project was done on March, 20, 2020 at 2:30 p.m. and readings were taken under ten minute’s intervals which are under as follow:

Table.1. Experimental Readings

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Inlet Pressure (Bar)</th>
<th>Outlet Pressure (Bar)</th>
<th>Time (min)</th>
<th>Evaporator Temp. (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>0.8</td>
<td>10</td>
<td>34.5</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>0.8</td>
<td>20</td>
<td>31.6</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>0.6</td>
<td>30</td>
<td>28.1</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>0.5</td>
<td>40</td>
<td>25.7</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>0.5</td>
<td>50</td>
<td>21.9</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>0.4</td>
<td>60</td>
<td>18.8</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>0.3</td>
<td>70</td>
<td>16.4</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>0.2</td>
<td>80</td>
<td>14.8</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>0.2</td>
<td>90</td>
<td>12.2</td>
</tr>
</tbody>
</table>

The properties of LPG at 5.525 bars are
Enthalpy $h_1 = 107.3$ kJ/Kg
$h_2 = 294.8$ kJ/kg
$hg = 482.3$ kJ/kg.
$h_3 = 562.46$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
$= 0.2162 \times 1000/ (9.45/10000) \times 5400$
$= 42.39$W

COP of the LPG Refrigeration System:
$COP = RE/W$
$= 267.66/42.39$
$= 6.3$

9. 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.

10. CONCLUSION:

Our main aim was to use high pressure of the LPG gas stored in cylinder for producing cooling effect. In the process of refrigeration, adiabatic expansion of LPG takes place 100 psi to 10 psi. And due to this thermodynamically it absorbs heat from surrounding and cooling effect can be achieved. This cooling effect can be in the range 15 to 50 degrees. 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.

11. REFERENCES:


