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Performance Evaluation of Electricity free Refrigerator using LPG as Refrigerant

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ABSTRACT

This project 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 evaporator temperature reached 5°C with an ambient temperature of 35°C. Also from the experiment which done in 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.

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I. INTRODUCTION

The term 'refrigeration' in a broad sense is used for the process of removing heat (i.e. Cooling) from a substance. It also 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 .For example, if some space (say in cold storage) is to be kept at -2 °C, we must continuously extract heat which flows into it due to leakage through the walls and also the heat, which is brought into it with the articles stored after the temperature is one reduced to -2 °C. Thus in a refrigerator, heat is virtually being pumped from a lower temperature to a higher temperature. The refrigeration system is known to the man, since the middle nineteenth century. The scientist, of the time, developed a few stray machines to achieve some pleasure. But it paved the way by inviting the attention of scientist for proper studied and research.

They 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. Hebrews, Greeks, and Romans places large amounts of snow into storage pits dug into the ground and insulated with wood and straw. The ancient Egyptians filled earthen jars with boiled water and put them their roofs, thus exposing the jars to the night's cool air. In India, evaporating cooling was employed.

When a liquid vaporizes rapidly, it expands quickly. The rising modules of vapor abruptly increase their kinetic energy and this increase is drawn from the intermediate surroundings of the vapor. These surroundings are therefore cooled. The intermediate stage in the history of cooling foods was to add chemicals like sodium nitrate or potassium nitrate to water causing the temperature to fall. Cooling wine via above method was recorded in 1550. The energy crisis persists all across the globe. We think of recovering the energy which is already spent but not being utilized further, to overcome this crisis with no huge 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 NO COST Cooling Systems. Petroleum gas is stored in liquefied state before its utilization as fuel. The energy spent for pressurizing and liquefying is not recovered afterwards. If it is expanded in an evaporator, it will get vaporized and absorb heat to produce cooling. This property has been used for refrigeration and air conditioning. So that the liquefied form of LPG can be used for cooling and the expanded gas (LPG) can be further used for combustion as a fuel.

II. DESIGN OF LPG REFRIGERATING SYSTEM

The main parts in this system:

1. Copper Tubes (For carrying LPG cylinder to filter before capillary)
2. Capillary tube
3. Valves (Gas supply control valves
4. Evaporator

1. **Copper Tubes Air**-Conditioning and Refrigeration Systems—

Copper is the preferred material for use with most refrigerants. Because of its good heat transfer capacity as well as corrosion resistance and cheaper in cost. As for all materials, the allowable internal pressure for any copper tube in service is based on the formula used in the American Society of Mechanical Engineers Code for Pressure Piping (ASME B31):[7]

P = 2S (tmin – C)/ Dmax – 0.8 (tmin – C) Where:

P = allowable pressure, bar

S = maximum allowable stress in tension, bar tmin = wall thickness (min.), in mm

Dmax = outside diameter (max.), in mm

C = a constant for copper tube, because of copper's

superior corrosion resistance, the B31 code permits the factor C to be zero. Thus the formula becomes: P = 2Stmin/Dmax – 0.8tmin

According to the pressure 100 psi the tube outside

diameter is become = 7 mm and the thickness of the tube is = 1.5 mm.

Valves

In this system we have used two flow control valves of globe type of 4 mm of internal diameter.

Evaporator

Evaporators are heat exchanger. They are designed aiming at accomplishing a heat transfer duty at the penalty of pumping power. There are two well-established methods available for the thermal heat exchanger design, the log-mean temperature difference (LMTD) and the effectiveness/number of transfer units (e-Ntu). The second has been preferred to the former as the effectiveness, defined as the ratio between the actual heat transfer rate and the maximum amount that can be transferred, provides a 1st-law criterion to rank the heat exchanger performance, whereas the number of transfer units compares the thermal size of the heat exchanger with its capacity of heating or cooling material. [1]

In general, evaporators for refrigeration applications are designed considering the coil flooded with two phase refrigerant, and also a wall temperature close to the refrigerant temperature so that the temperature profiles along the streams are not constant, in these cases, the heat transfer rate if it is calculated from:[2]

$Q = m.cp (To – Ti) = ε.m.cp (Ts − Ti)$

Where m is the mass flow rate, Ti, To and Ts are the inlet, outlet and surface temperatures, respectively,

$Q=h × As (Ts-Tm)$

Is the heat transfer rate, Tm is the mean flow temperature over the heat transfer area, As, and ε is the heat exchanger effectiveness, calculated from :

$e = 1 – \exp(−NTU)$

Where NTU is the number of transfer units. We have selected the plate and tube type evaporator because it provides a gentle type of evaporation with low residence time. It also preserves the food and other products from bacterial attack. It requires low installation cost.

Design calculations for 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 3mm thickness which enclose six thermocol sheets of 10 mm thickness. The areas for these sheets are as follows:

Area1 = 265×135 = 0.03578 m2,
Area2 = 265×325 = 0.08612 m2,
Area3 = 265×135 = 0.03578 m2,
Area4 = 265×325 = 0.08612 m2,
Area5 = 325×135 = 0.04388 m2,
Area6 = 325×135 = 0.04388 m2,

Thermal conductivity of plywood kp = 0.12 W/m.k
Thermal conductivity of thermo coal kt = 0.02 W/m.k
Thickness of plywood = 3 mm
Thickness of thermo coal = 10 mm
Temperature of atmosphere = 35 0C = 298 K
Temperature of evaporator = -9 0C = 264 K

Heat flow from area 1 due to conduction
Q1 = (Ta-Te)/ (Rthp + Rtht)
= (Ta-Te)/ ((Lp/KP.A) + (Lt/Kt.A))
= (294-264)/ (0.698+13.97)= 2.317W

Heat flow from area 2 due to conduction

Q2 = 5.58 W, Q3 = 2.32 W, Q4 = 5.58 W, Q5 = 2.84 W Q6 = 2.84 W

Total heat flow from all areas due to conduction = 21.47 W Heat flow from evaporator due to convection

Inside heat transfer coefficient = 30 W/m2.K Outside heat transfer coefficient = 10 W/m2.K Rate of heat transfer Q [6]

Q =U.A. (Ta-Te)

The overall heat transfer coefficient

1/U = (1/Uo) + (Lp/kp) + (Lt/kt) + (1/Ui)

1/U = 0.649

U = 1.54 W/m2.K

Rate of heat transfer from area 1

Q1 = 1.54×0.03578(298-264) = 1.873W

Q2 = 4.50 W, Q3 = 1.873 W, Q4 = 4.50 W, Q5 = 2.29 W Q6 = 2.29 W

Total heat flow from all areas due to convection = 17.326 W Heat transfer due to radiation Q

Q = σT4

= 5.67× 10-8(35-(-9.3)) 4

= 0.21W

Total heat flow from evaporator due to conduction, convection and radiation Qt Qt = 21.47+17.326+0.21

=39.006W

Experiment is done on 20 march 2017 at 12 pm and readings were taken at 10 minutes interval which are tabulated in table below,

III. EXPERIMENTAL READINGS

Time	Inlet pressure(bar)	Outlet pressure(bar)	Water temp(c)	Evaporator temp(c)
10	5.516	1.45	25.2	18.0
20	5.415	1.43	17.2	15.2
30	5.310	1.36	14.21	13.1
40	5.200	1.35	13.12	12.11
50	5.150	1.31	12.10	10.09
60	5.030	1.30	12.10	10.00

Size of refrigerator: - 335×265×135 mm³ Initial temperature of water: - 30^{0}C Initial temperature of evaporator: - 33^{0}C Specific heat of LPG vapor is 1.495kJ/Kg K.

The graph of temperature v/s time of the water and evaporator are shown below:

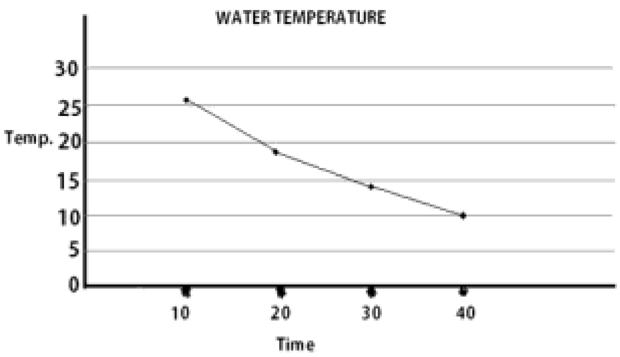

Chart 1. Temperature of water v/s Time

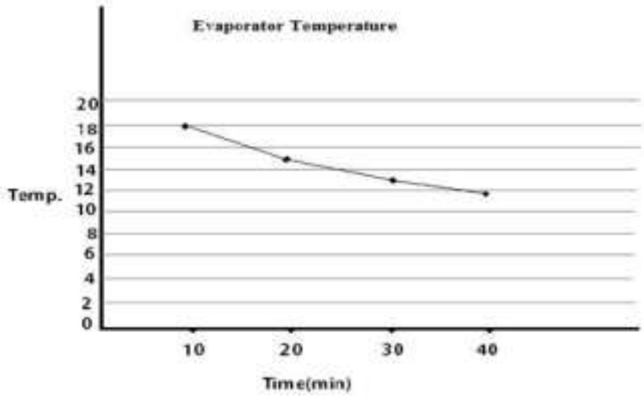

Chart 2. Temperature of evaporator v/s time

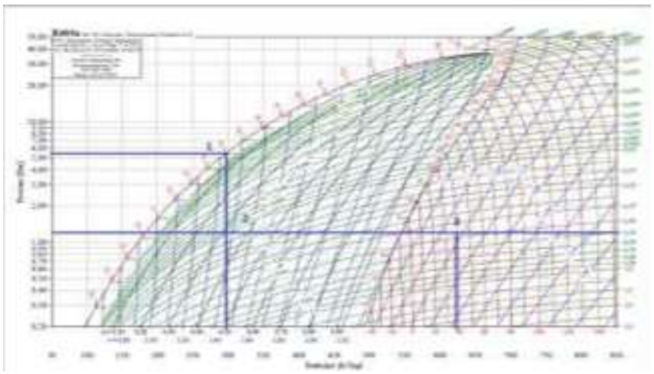

Fig. p-h diagram of LPG refrigeration system [3]

Refrigerating effect [4]

The properties of LPG at 5.516 bars are Enthalpy h1 = 630.3 kJ/Kg

Temp. t1= 4 ^{0}C

The properties of LPG at 1.316 bars are Enthalpy h3 = 307.3 kJ/Kg

Temp. t3= -30 ^{0}C

Heat extracted from evaporator in 1 hour (Qeva) = Heat gained by LPG (QLPG) So the refrigerating effect is = h3-h2

= 630.3-307.3

= 323kJ/Kg

For work input we have a LPG cylinder of 14.5 Kg. Therefore the work input is amount of energy required for filling of 1 cylinder. A typical LPG filling plant has the following major energy consuming [5].

Equipment:-

1. LPG pumps
2. LPG compressors
3. Conveyors
4. Blowers
5. Cold repair facilities including painting

6. Air compressors and air drying units. Etc

Some of the LPG filling plants uses a comprehensive monitoring technique for Keeping track of energy consumption per ton basis. As per PCRA Energy Audit [5]
1. Consumption = 40×4200=168000kWh
2. For lighting energy consumption= 227340kWh
3. LPG compressor consumption= 153360 kWh
1. Total consumption for LPG pumps
One pump having 40 kW motor and 96 m head or 150cubic meter /hour discharge
Annual operating = 4200 hrs
Annual energy 6 hrs /day in 350 days

= 168000+227340+153360
= 548700kWh
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
= 3.1354kWh
So 1 kg of LPG is
= 3.1354/14.5
=0.2162 kWh
We run the set up for 1 hr
= 0.2162×1000/ (9.45/10000) ×3600
= 63.55W

COP OF THE LPG REFRIGERATION SYSTEM
COP = (h3-h2)/w
= (630.3-307.3)/63.55
= 5.08

IV. CONCLUSION

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. It does not require any external energy sources to run the system and no moving part so maintenance is also very low. This paper also concluded that, we can use exhaust LPG for cooking as usual and also cooling effect is obtained. With further development it is possible to use the LPG for refrigeration as it is cheap, sufficiently available, and environmental friendly.

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