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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. 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. 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. The use of LPG for refrigeration purpose can be environment friendly since it has no ozone depletion potential (ODP). Usually LPG is used as a fuel for cooking food in houses, restaurants, hotels, etc.. and the combustion products of LPG are CO_2 and H_2O.

Keywords — LPG Refrigerant, Domestic Refrigerator, Expansion, Refrigerating Effect, Cooling Effect, COP, Capillary tube, Environment friendly

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INTRODUCTION: pressure of LPG is dropped due to expansion and phase change of LPG occurs in an isenthalpic process. Due to phase change from liquid to gas latent heat is gained by the liquid refrigerant and the temperature drops. In this way LPG can produce refrigerating effect for a confined space.

From experimental investigations, we have found that the COP of a refrigerator which uses LPG is higher than a domestic refrigerator.

LPG REFRIGERATION

In India, more than 80% of the domestic refrigerator utilizes HFC 134a as refrigerant, due to its excellent thermodynamic and thermo physical properties. But HFC 134a has a high global warming potential (GWP) of 1300. There is a need to evaluate various refrigerant options considering the existing refrigerators in the field and for the future market. CFC's are principally destroyed by ultraviolent radiations in the stratosphere; the chlorine released in the high stratosphere catalyzes the decomposition of ozone to oxygen; and ultraviolent radiations penetrate to lower altitudes. The ozone impact of car air conditioners also cannot be ignored. Hydro fluorocarbons (HFC's) can be thought of as a replacement, but unfortunately the radiation properties of HFCs like R-134a make them powerful global warming agents. HFC 134a and the HC blend have been reported to be substitutes for CFC 12, but they have their own drawbacks in energy efficiency, flammability and service ability aspects of the systems. HFC 134a is not miscible with mineral oil, and hence polyol ester oil is recommended, which is highly hygroscopic in nature.

LIQUEFIED PETROLEUM GAS (LPG).

LPG is a mixture of commercial butane and commercial propane having both saturated and unsaturated hydrocarbons. LPG marketed in India shall be governed by Indian Standard Code IS-4576 (Refer Table 1.0) and the test methods by IS-1448.

PHYSICAL PROPERTIES AND CHARACTERISTICS OF LPG

DENSITY

LPG at atmospheric pressure and temperature is a gas which is 1.5 to 2.0 times heavier than air. It is readily liquefied under moderate pressures. The density of the liquid is approximately half that of water and ranges from 0.525 to 0.580 @ 15 deg. C. Since LPG vapour is heavier than air, it would normally settle down at ground level/ low lying places, and accumulate in depressions.

VAPOUR PRESSURE

The pressure inside a LPG storage vessel/ cylinder will be equal to the vapour pressure corresponding to the temperature of LPG in the storage vessel. The vapour pressure is dependent on temperature as well as on the ratio of mixture of hydrocarbons. At liquid full condition any further expansion of the liquid, the cylinder pressure will rise by approx. 14 to 15 kg./sq.cm. for each degree centigrade. This clearly explains the hazardous situation that could arise due to overfilling of cylinders. FLAMMABILITY

LPG has an explosive range of 1.8% to 9.5% volume of gas in air. This is considerably narrower than other common gaseous fuels. This gives an indication of hazard of LPG vapour accumulated in low lying area in the eventuality of the leakage or spillage. The auto-ignition temperature of LPG is around 410-580 deg. C and hence it will not ignite on its own at normal temperature. Entrapped air in the vapour is hazardous in an unpurged vessel/ cylinder during pumping/ filling-in operation. In view of this it is not advisable to use air pressure to unload LPG cargoes or tankers.

COMBUSTION

The combustion reaction of LPG increases the volume of products in addition to the generation of heat. LPG requires upto 50 times its own volume of air for complete combustion .Thus it is essential that adequate ventilation is provided when LPG is burnt in enclosed spaces otherwise asphyxiation due to depletion of oxygen apart from the formation of carbon-dioxide can occur.

ODOUR

LPG has only a very faint smell, and consequently, it is necessary to add some odorant, so that any escaping gas can easily be detected. Ethyl Mercaptan is normally used as stanching agent for this purpose. The amount to be added should be sufficient to allow detection in atmosphere 1/5 of lower limit of flammability or odour level 2 as per IS: 4576.

COLOUR

LPG is colourless both in liquid and vapour phase. During leakage the vaporisation of liquid cools the atmosphere and condenses the water vapour contained in them to form a whitish fog which may make it possible to see an escape of LPG.

TOXICITY

LPG even though slightly toxic, is not poisonous in vapour phase, but can, however, suffocate when in large concentrations due to the fact that it displaces oxygen. In view of this the vapour posses mild anaesthetic properties.

Hazards of LPG

1. LPG is approximately twice as heavy as air when in gas form and will tend to sink to the lowest possible level and may accumulate in cellars, pits, drains etc.
2. LPG in liquid form can cause severe cold burns to the skin owing to its rapid vaporisation.
3. Vaporisation can cool equipment so that it may be cold enough to cause cold burns.
4. LPG forms a flammable mixture with air in concentrations of between 2% and 10%.
5. It can, therefore, be a fire and explosion hazard if stored or used incorrectly.
6. Vapour/air mixtures arising from leakages may be ignited some distance from the point of escape and the flame can travel back to the source of the leak.
7. At very high concentrations when mixed with air, vapour is an anesthetic and subsequently an asphyxiate by diluting the available oxygen.
8. A vessel that has contained LPG is nominally empty but may still contain LPG vapour and be potentially dangerous. Therefore treat all LPG vessels as if they were full.

PARTS OF LPG REFRIGERATOR:

LPG CYLINDER:

LPG is a mixture of butane and isobutene. It is generally stored at 12.7 bar for house hold purpose cylinder. By using a suitable regulator LPG is sent into capillary tube. LPG is used as a fuel for domestic, industrial, horticultural, agricultural, cooking, heating and drying processes. LPG can be used as an 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.

LPG gas cylinder

Capillary Tube:

The capillary tube is the commonly used throttling device in the domestic refrigeration. The capillary tube is a copper tube of very small internal diameter. It is of very long length and it is coiled to several turns so that it would occupy less space. The internal diameter of the capillary tube used for the refrigeration applications varies from 0.5 to 2.28 mm (0.020 to 0.09 inch). The capillary tube is shown in picture. The decrease in pressure of the refrigerant through the capillary depends on the diameter of capillary and the length of capillary. Smaller is the diameter and more is the length of capillary more is the drop in pressure of the refrigerant as it passes through the capillary tube.

4.3.2 EVAPORATOR:

The evaporators are another important parts of the refrigeration systems. Through the evaporators the cooling effect is produced in the refrigeration system. It is in the evaporators when the actual cooling effect takes place in the refrigeration systems. For many people the evaporator is the main part of the refrigeration system, consider other part as less useful. 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 substance.

Evaporator

The evaporators are used for wide variety of diverse application in refrigeration and hence the

available in wide variety of shape, sizes and designs. They are also classified in different manner depending on the method of feeding the refrigerant, construction of the evaporator, direction of air circulation around the evaporator, application and also the refrigerant control. In the domestic refrigerators the evaporators are commonly known as freezers since the ice is made in these compartments. In the evaporators the refrigerant enters at very low pressure and temperature after passing through the capillary tube. This refrigerant absorbs the heat from the substance that is to be cooled so the refrigerant gets heated while the substance gets cooled. Even after cooling the substance the temperature of the refrigerant leaving theevaporator is less than the substance. In the large refrigeration plants the evaporator is used for chilling water.

PRESSURE GUAGES:

Many techniques have been developed for the measurement of pressure and vacuums. Instruments used to measure pressure are called pressure gauges or vacuum gauges.

Fig: Pressure gauge

High Pressure Pipes:

The range of high pressure pipes covers most application where there is a requirement to transfer gas at high pressure. They consist of a steel pipe with steel ball fitted to both ends. Two swivelling connection nipples press these balls against the seating of the connecting hole and thus sealing against gas leakage.

All pipes are pressure tested to 100 M Pa (14,500 psi) over recommended working pressure.

Fig 4.3.5: High pressure pipe

High Pressure Regulator:

This type of regulator is used to send high pressure gas from the cylinders. These are mainly used in functions to Bhatti stoves.

Fig: High pressure regulators

DESIGN OF BASICCOMPONENTS OF LPGREFRIGERATION SYSTEM

Two main components (capillary tube and evaporator) have been designed in this system

DESIGN OF CAPILLARY TUBE

The capillary tube is a fixed restriction-type device. It is a long and narrow tube connecting the condenser directly to the evaporator. The pressure drop through the capillary tube is due to the following two factors:

1. Friction, due to fluid viscosity, resulting in frictional pressure drop.
2. Acceleration, due to the flashing of the liquid refrigerant into vapour, resulting in momentum pressure drop.

Design parameters for capillary tube are:

Cylinder size = 14 kg,

$D_{cylinder}$= 295 mm $d_{capillary}$ =1.05mm.

DESIGN OF EVAPORATOR

The evaporator is the component of a refrigeration system in which heat is removed from air, water or any other body required to be cooled by the evaporating refrigerant. In experimental setup plate and tube type evaporator has been used because it provides a gentle type of evaporation with low residence time. It also preserves the food and other products from bacterial attack and requires low installation cost.

Construction of LPG Refrigerator:

The LPG refrigerator is shown in the figure. We make the one box of the Thermo-coal sheet. The thermo-coal sheet size is 15mm used for the LPG refrigerator. The size of the evaporator is 355*254*152 mm^3. We kept the thermo-coal sheet because the cold air cannot transfer from inside to outside of refrigerator. And the evaporator is wrapped totally with aluminum tape. The schematically diagram of the LPG refrigeration system is shown in below diagram. The gas cylinder is connected to high pressure regulator, which is connected to high pressure pipes. To the other end of the high pressure pipes pressure guage is connected. To another end a copper tube is connected which is connected to the capillary tube. The capillary tube is fitted with evaporator. The evaporator coil end is connected to the stove by another high pressure pipe. One pressure guage is put between capillary tube and cylinder and another is put at the end of the evaporator.

Fig Construction of LPG Refrigerator

WORKING OF LPG REFRIGERATOR:

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

1. LPG is stored in the LPG cylinder under high pressure. When the gas tank of regulators is opened then high pressure LPG passes through the high pressure pipe. This LPG is going by high pressure gas pipe to capillary tube.
2. High pressure LPG is converted in low pressure at capillary tube with enthalpy remains constant.
3. After capillary tube, low pressure LPG is passed through the evaporator. LPG is converted into low pressure and temperature vapor from and passes the evaporator which absorbs heat from the chamber. Thus the chamber becomes cool down. Thus we can achieve cooling effect in refrigerator.
4. After passing through the evaporator low pressure LPG is passed through the pipe to burner. And we can use the low pressure of LPG in burning processes.

The LPG Refrigerator is work on the simpleVapour Compression Refrigeration system. The working of VCR system is as follows:
Process 2-3: When the compressor is started, it draws the low pressure vapour from the evaporator at state 2 and compresses it isentropically to sufficiently high pressure up to state 3. Since in compression work is done on the vapour, its temp also increases and hence it isconverted 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 form which it absorbs the heat from the cooling chamber. Thus the cooling chamber cools down.
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.

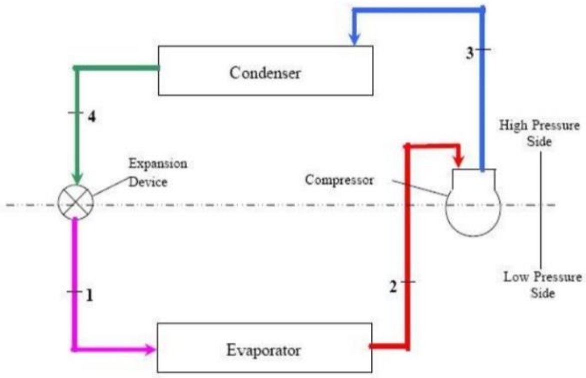

Fig-6.2.a: Schematic diagram of simple VCRs

The idea behind working of 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 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 goes in the capillary tube from high pressure pipe. In the capillary tube this high pressure LPG is converted into low pressure and hence low temperature because of expansion of LPG gas in capillary tube.
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.
The actual setup and construction of LPG refrigeration system is shown in the following figure.

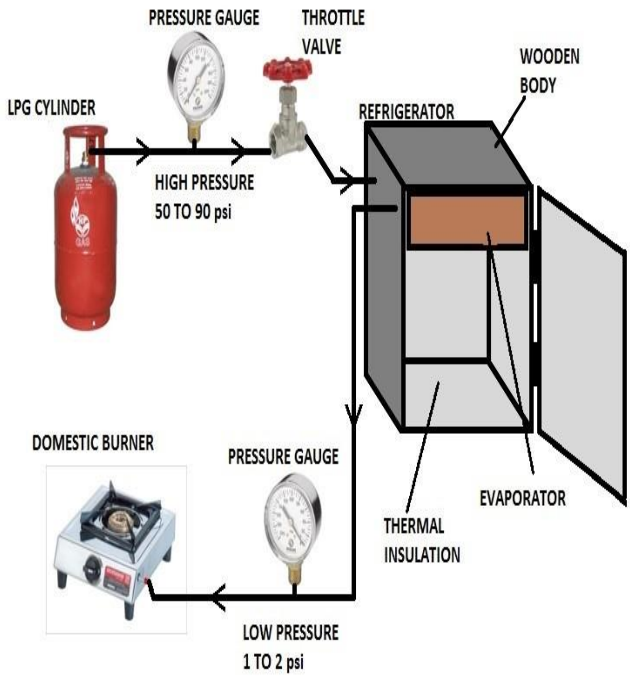

Fig 6.2.b: LPG refrigeration and heating system.

ADVANTAGES,DISADVANTAGES AND APPLICATIONS

ADVANTAGES:

1. Use of LPG as a refrigerant also improves the overall efficiency of by 10 to 20%.
2. The ozone depletion potential (ODP) of LPG is 0 and Global warming potential (GWP) is 8 which is significantly negligible as compare to other refrigerant.
3. A part from environment friendly, use of LPG also gives us lot of cost advantages.
4. There is 60% reduction in weight of the system due to higher density of LPG.
5. This fridge works when electricity is off.
6. The parts are effectively silent in operation.
7. Running cost is zero
8. Eliminates the compressor and condenser.

DISADVANTAGES:

1. Efficiency is poor.
2. Leakage of LPG causes the blast.
3. Repairing and servicing of the system is difficult.
4. System is very bulky

APPLICATION:

1. It can play an important role in restaurants where continuously cooling and heating is required.
2. It can be used in chemical industries for refrigeration purpose.
3. It can be useful in remote parts where electricity is not available.
4. It can be used in refineries where consumption of LPG is high.
5. The system can universally be used in industrial central cooling and domestic refrigeration and air conditioning as well.
6. It can be used in automobiles running on LPG or other Gaseous fuels for air conditioning.
7. It can be useful in remotes parts where Electricity is not available.
8. Cooling and storage of essentials in remote areas and in emergency vehicles, such as storage of essential bio-chemicals, injections, etc in an ambulance, is easily possible.
9. It can be used for zero cost air-conditioning of spaces like airports, shopping malls, etc which have their own gas turbine power-plants.

CONCLUSION

The aim of the LPG refrigerator was to use LPG as a refrigerant and utilizing the energy of the high pressure in the cylinder for producing the refrigerating effect. We have the LPG at a pressure of 12.41 bar in Domestic 14.5 kg cylinder equipped with a high pressure regulator and this pressure has reduced up to 1.41 bar with the help of capillary tube. But if we use a low pressure regulator as is the practice in conventional domestic LPG gas stove, the pressure of LPG after the expansion device and before the burner would be different. So we have calculated the refrigerating effect with the help of changes in properties of LPG (pressure, temperature, and enthalpy) before and after the evaporator using high pressure regulator and the amount of refrigerating effect is determined. With this energy input the COP of the LPG refrigerator is 5.08 and it is greater than the domestic refrigerator. But in the future scope the result may differ if energy input for 1Kg of LPG production, would be taken from the energy audit report of any refinery.

This system is cheaper at initial as well as running cost. It does not require an external energy sources to run the system and no moving part in the system. So maintenance cost is also very low. This system is most suitable for hotel, industries, refinery, chemical industries where consumption of LPG is very high.

We conclude that:

1. Propane is an attractive and environmentally friendly alternative to CFCs used currently.
2. Mass flow rate increases with increase in capillary inner diameter rand coil diameter where as mass flow rate decreases with increase in length. It was observed that the COP of system increases with similar change in geometry of capillary tube.
3. Cooling capacities were obtained order of about three- to four fold higher for LPG than those for R- 12. capillary tube. COP of LPG refrigerator was higher than that of R134a by about7.6%. LPG seems to be

an appropriate long-term candidate toreplaceR134a in the existing refrigerator,

4. High COP values were obtained No operation problems have been encountered compressor. The use of LPG as a replacement refrigerant can contribute to the solution of (ODP) problem and global warming potential.

LITERATURESURVEY

1 A.Baskaran&P.Koshy Mathews

A Performance Comparison of Vapour Compression Refrigeration System Using eco-friendly refrigerant of low Global Warming Potential VCR system with the new R290/R600a refrigerant mixture as a substitute refrigerant for CFC12 and HFC 134a. The refrigerant R290/R600a had a refrigerating capacity 28.6% to 87.2% higher than that of R134a.

2 A.Baskaran&P.Koshy Mathews

A Performance Comparison of Vapour Compression Refrigeration System Using Eco Friendly Refrigerants of Low Global Warming Potential. R600a performance have a slightly higher than coefficient(COP) R134a for the condensation temperature of 50 C^{o} and evaporating temperatures ranging between -30 C^{o} and10^{o}C.Hence, The coefficient performance (COP) of this mixture was up to 5.7% higher.

3 M. Mohanraj et. al. , have studied experimentally the drop in substitute for R134a with the environment friendly, energy efficient hydrocarbon (HC) mixture which consists of 45% HC290 and 55% R600a at various mass charges of 50g, 70g and 90g in domestic refrigerator. The experiments were carried out in 165 liters domestic refrigerator using R134a with POE oil as lubricant. The discharge temperatures of HC mixtures are found to be lower than R134a by 13.76%, 6.42% and 3.66% for 50g, 70g and 90g respectively. The power consumption of HC mixture at 50g and 70g are lower by 10.2% and 5.1% respectively and 90g shows higher power consumption by 1.01%. The percentage reduction in pull down time is 18.36%, 21.76% and 28.57% for 50, 70 and 90g mass charges respectively when compared to R134a. The HC mixture because of its high energy efficiency will also reduce the indirect global warming. In conclusion HC mixture of 70g is found to be an effective alternative to R134a in 165 liters domestic refrigerator.

4 B.O.Bolaji,have Experimental study of R152a/R32 to replace R134a in a domestic refrigerator and find out that COP obtained by R152a is 4.7% higher than that of R134a. COP of R32 is 8.5% lower than that of R134a and propane is an attractive and environmentally friendly alternative to CFCs used currently used.

5 R.W.James&J.F.Missenden, have use of propane in domestic refrigerators and conclude that he implications of using propane in domestic refrigerators are examined in relation consumption, compressor costs, availability, to energy lubrication, environmental factors and safety propane is an attractive and

environmentally friendly alternative to CFCs used currently.

6 Bilal A. Akash et. al, has conducted performance tests on the performance of liquefied petroleum gas (LPG) as a possible substitute for R12 in domestic refrigerators. The refrigerator which is initially designed to work with R12 is used to conduct the experiment for LPG (30% propane, 55% n-butane and 15% isobutane). Various mass charges of 50, 80 and 100g of LPG were used during the experimentation.LPG compares very well to R12. The COP was higher for all mass charges at evaporator temperatures lower than −15˚C. Overall, it was found that at 80g charge, LPG had the best results when used in this refrigerator. The condenser was kept at a constant temperature of 47˚C. Cooling capacities were obtained and they were in the order of about three to fourfold higher for LPG than those for R12

7 M. Fatouh et. al. investigated 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. 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 refrigerator were lower than those of R134a by about 7.6%, 5.5% and 4.3%, respectively. COP of LPG refrigerator was 7.6% higher than that of R134a. 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 drop in replacement for R134a, to have the better performance, optimization of capillary length and refrigerant charge was needed.

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