Waste Heat Recovery from LPG- Review Paper

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***Abstract*— The LPG is cheaper and possesses an environmental free in nature with no ozone depletion potential (ODP). Also LPG is available as a side product in local refineries. This work investigates the result of an experimental study carried out to determine the performance of domestic refrigerator when a propane-butane mixture is liquefied petroleum gas (LPG) which is available and comprises 56.4% butane, 24.4% propane, and 17.2% isobutene. An experimental investigation of Performance is carried out by the effect of changing capillary tube length, capillary tube inner diameter and capillary coil diameter on the mass flow rate of refrigerant in an adiabatic helical capillary tube. Large amount of electricity supply is not available easily in large part of under development country like India. It will also prove to be an effective for remote area such as research sites, mines, & deserts where electricity is generally not available. The results of the present work indicate the successful use of this propane-butane mixture as an alternative refrigerant to CFCs and HFCs in domestic refrigerator. It would include Experimental setup of working model and detailed observation of the LPG refrigerator and represents its application in refinery, hotel, chemical industries where requirement of LPG is more.**

***Keywords*— Refrigeration, LPG, Heat recovery.**

I. INTRODUCTION

According to the Indian Government, the refrigerator is the 3rd heaviest consumer of power amongst household appliances. It is one of the few appliances that is running 365 days a year, increasing the importance, whenever possible, to have an eco-friendly refrigerator in your household. A new eco-friendly refrigerator in 2006 was estimated to consume 481 kilowatt hours per year. The energy consumption of refrigerators has improved steadily year over year.It works on the principle that during the conversion of LPG into gaseous form the expansion will be take place. Due to this expansion in LPG gas the pressure will drops. And the volume will be increase this will be result into dropped in temperature and it acts as refrigerant. According to second law of thermodynamics, this process can only be performed with the aid of some external work. It is thus obvious, that supply of power (say electrical motor) is regularly required to drive a refrigerator. The substance which works in a heat pump to extract heat from a cold body and to deliver it to a hot body is called refrigerant.

When we think about refrigerator we only remember refrigeration in kitchen, but actually divided in three types in which each type having their own type of functioning. One which used in Industrial purpose called as Industrial refrigerator.Which used as food processing, chemical processing & cold storage. Industrial refrigeration, which frequently uses ammonia refrigeration to maintain temperature, is necessary for computer, foodstuffs, blood, vaccines, and quite a few other goods that must maintain a constant and steady temperature at all times. Temperatures matters in industrial refrigeration companies to pay attention at all times. Domestic refrigerant consumes 17500 metric tons of traditional refrigerant as CFC, HFC and which contribute high ozone depletion potential (ODP) and Global warming potential (GWP). Good progress is being made with the phase out of CFC 22 from new equipment manufacture by replacing LPG since it possesses an environmentally friendly nature with no ODP. LPG is expected to results in comparable product efficiencies based on its characteristics. Therefore, this two types of refrigerants (LPG and CFC 22) to be examined using a modified domestic refrigerator in term of their performance characteristics parameters such as pressure and temperature at specified location at the refrigerator and the safety requirements while conducting the experiment. By performing the tests on new system, it is indicate that the successful of using LPG as an alternative refrigerant to replace CFC 22 in domestic refrigerators is possible by getting LG.

Waste heat recovery is the collection of heat which is created as an undesired by-product of the operation in everyday processes such as refrigeration, air-conditioning etc. Waste heat losses arise both from equipment inefficiencies and from thermodynamic limitations (second law of thermodynamics). A waste heat recovery unit (WHRU) is an energy recovery heat exchanger which recovers heat from hot stream which is generally a by-product of any process. For functioning of an apparatus like refrigerator etc., this heat has to be rejected into the environment.

Hence, before rejecting this energy into the environment, we utilize a part of this energy in heating applications. Various waste heat sources are available such as domestic and urban waste which includes heat losses in cooking appliances, heat losses in air conditioners, heat losses in HVAC systems etc. Waste heat recovery system can be used in various applications but in present study, we shall focus on the use of waste heat recovery in air cooled domestic refrigerator.

The vapor compression refrigeration process includes 4 stages i.e. compression, condensation, expansion and evaporation. Out of these stages, heat rejection takes place in condensation process. This heat is rejected into the atmosphere (waste heat) and hence there is an opportunity to recover and re-use that heat so that overall system efficiency can be maximized

Problem Statement:-

Each home in the country mostly have refrigerators at home as we use it keep food cold, preserve them and keeping them away from bacterial growth to keep them safe until we eat them. If you think about it, living without appliances like this can be very difficult but refrigerators are not always just good. There are actually disadvantages out from owning one. Most of us would think that it would be better to have those problems than have no refrigerator at all but there are facts you should know and take into consideration about them. One of the biggest disadvantages that this appliance can give you is the cost of keeping it on.

One of the disadvantages of refrigerators is that they are environmentally unfriendly and dangerous if not disposed of properly. If doors are not removed from old refrigerators with locking doors, they pose a hazard to children who may get trapped inside. The refrigerator also contains refrigerant that can be damaging to the environment because of chlorofluorocarbon (CFC) content. This material should be recycled. Otherwise the CFCs can escape into the air. This material is suspected to be the cause of depletion of the earth's ozone layer

Objective of the work:-

1. Cooling is free of cost as no electricity is needed for operating the air conditioner and refrigerator.
2. LPG is not consumed during cooling process, only expanded and further used for cooking, as automobile fuel or for any industrial purposes.
3. The product is a green technology and is eco- friendly, as if eliminates the use of ozone-depleting refrigerants

Aim and Scope of the work:-

Positive result of experimentation pushes me to go ahead with this normal product and introduce new product range in the field of refrigeration. Which focus on the restaurant and Community hall, and mid-day meal of school and college to decrease the product and cost and for preserving vegetables ,milk etc.at small lair and snacks shop by increase the portability of the refrigerator by reducing the weight and eliminating the compressor with no cost of refrigerating and light weight and light maintenance free product.

- It may very useful for the desert, research and mines area and many other area of under developed country, where electricity not easily available.
- It can be apply for the system as an air conditioning in LPG cars.

This system most suitable for hotel, industries, refinery, chemical industries where consumption of LPG is very high.

Methodology:-

A. LPG Gas Cylinder

LPG is Liquefied Petroleum Gas. This is general description of Propane (C3H8) and Butane (C4H10), either stored separately or together as a mix. This is because these gases can be liquefied at a normal temperature by application of a moderate pressure increases, or at normal pressure by application of LPG using refrigeration 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 propellant for aerosol, in addition to other specialist applications. LPG can also be used to provide lighting through the use of pressure lantern. LPG is Liquefied Petroleum Gas. This is general description of Propane (C3H8) and Butane (C4H10), either stored separately or together as a mix. This is because these gases can be liquefied at a normal temperature by application of a moderate pressure increases, or at normal pressure by application of LPG using refrigeration. 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 propellant for aerosol, in addition to other specialist applications. LPG can also be used to provide lighting through the use of pressure lantern.

Fig. 1 lpg cylinder

B. 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. When the refrigerant enters in the capillary tube, its pressure drops down suddenly due to very small diameter. 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 it.

Fig. 2 capilary tube

C. Evaporator

The evaporators are another important parts of the refrigeration systems. It through the evaporators that the cooling effect is produced in the refrigeration system.

Fig. 3 evaporator

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 from the substance. 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 the evaporator is less than the substance. In the large refrigeration plants the evaporator is used for chilling water. In such cases shell and tube type of heat exchanger are used as the evaporators.

D. Pressure Gauge

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. 4 pressure guage

A manometer could also referring to a pressure measuring instrument, usually limited to measuring pressures near to atmospheric. The term manometer is often used to refer specifically to liquid column hydrostatic instruments.

Catering to the requirements of to power and allied Industry, we offer quality array of stainless steel, weatherproof pressure gauges. Renowned for offering resistance in corrosive environments and modes, these find wide application in power generation, pollution control equipment, chemicals and petrochemicals and also exploration. These gauges are available in 63mm, 100mm, and 150mm sizes and can be customized as per client.

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II. LITERATURE REVIEW

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 studies 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 placed 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 molecules of vapor abruptly increase their kinetic energy and this increase is drawn from the immediate 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, as were the words "to refrigerate". Cooling drinks came into vogue by 1600 in France. Instead of cooling water at night, people rotate long-necked bottles in water in which salt petre had been dissolved. This solution could be used to produce very low temperature and to make ice. By the end of the 17 Century, iced liquors and frozen juices were popular in French society. The first known artificial refrigeration was demonstrated by William Cullen at the University of Glasgow in 1748.Beginning in the

1840, refrigerated cars were used to transport milk and butter. By 1860, refrigerated transport was limited to mostly seafood and dairy products. The refrigerated railroad car was patented by J.B.Sutherland of Detroit; Michigan in 1867. He designed an insulated car with ice bunkers in each end. Air came in on the top, passed through the bunkers, and circulated through the car by gravity, controlled by the use of hanging flaps that created differences in air temperature. Brewing was the first activity in the northern states to use mechanical refrigeration extensively, beginning with an absorption machine used by S.Liebmann's Sons Brewing Company in Brooklyn, New York in 1870.commercial refrigeration was primarily directed at breweries in the 1870 and 1891,nearly every brewery was equipped with refrigerating machines. Natural ice supply became an industry unto itself. By 1879, there were 35commercial ice plants in America, more than 200 a decade later, and 2,000 by 1909. No pond was safe from scraping for ice production, not even Thoreau's Walden Pond, where 1,000 tons of ice was extracted each day in 1847.However, as time went on, ice, as a refrigeration agent, became health problem. Says Bern Nagengast, co-author of Heat and Cold: Mastering the Great Indoors (published by the American Society of Heating, Refrigeration and Air-conditioning Engineers), "Good sources were harder and harder to find. By the 1890's, natural ice became a problem because of pollution and sewage dumping." Signs of a problem were first evident in the brewing industry

1. A.Baskaran & P.Koshy Mathews

A Performance Comparison of Vapour Compression Refrigeration System Using Eco Friendly Refrigerants of Low Global Warming Potential. R600a have a slightly higher performance coefficient(COP) than R134a for the condensation temperature of 50 C^0 and evaporating temperatures ranging between -30 C^0 and10^0C.Hence, The coefficient performance (COP) of this mixture was up to 5.7% higher.

2. 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 foundNto be an effective alternative to R134a in 165 liters domestic refrigerator.

3. R.W.James & J.F.Missenden

I have use of propane in domestic refrigerators and conclude that he implications of using propane in domestic refrigerators are examined in relation to energy consumption, compressor lubrication, costs, availability, environmental factors and safety propane is an attractive and environmentally friendly alternative to CF

4. A.S. Raut , U.S.Wankhede

I have worked on Selection of the Capillary Tubes for Retrofitting in Refrigeration Appliances and try to Use of alternative refrigerants play an important role in forming problems such as global warming and ozone depilationThe coefficient of performance of refrigeration appliances improves in case of retrofitting the capillary tube. It is possible to obtain the effective size (diameter & length) of capillary tube by using of mathematical techniques and by maintaining proper pressure equalization between condenser and evaporator.

III. INTRODUCTION TO 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.

3.1 Physical Properties And Characteristics

3.1.1 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.

3.1.2 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.

3.1.3 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.

3.1.4 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.

3.1.5 Odour

LPG has only a very faint smell, and consequently, it is necessary to add some odourant, so that any escaping gas can easily be detected. Ethyl Mercaptan is normally used as stenching 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.

3.1.6 Colour

LPG is colourless both in liquid and vapour phase. During leakage the vapourisation 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.

3.1.7 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 possesses mild anaesthetic properties.

TABLE I
LPG SPECIFICATION

Sr.no.	Characteristic	Requirement for commercial
Liquid state		
1	Density at 15 oC Kg/liter	0.557
2	Volume of liquid per kg at 15 oC Liters	1.85
3	Vapor pressure at 15 oC Bar	5.3
4	Gross Calorific Value Kcal/kg	11840
5	Boiling Point at atmospheric pressure oC	0
6	Dryness	No free entertained
7	Odour	Level 2
Vapour state		
8	Density at 15 oC Kg/m3	2.21
9	Volume of gas per kg at 15 oC m3	0.48
10	Latent heat of vaporization at 15 oC Kcal/kg	86
11	Gross Calorific Value Kcal/Nm3	26200
12	Net Calorific Value Kcal/Nm3	24100
13	Air required for combustion m3/m3	29
Chemical composition		
14	Ethane %	1 Max
15	Propane %	38 Max
16	Is-Butane %	19 Max

IV. CONCEPTUAL DEVELOPMENT OF LPG REFRIGERATOR

From the literature reviews and theoretical studies, it is clear that many operational and physical factors contribute to the Refrigerator performance of LPG. Since the targeted outcome of their research is a miniaturized LPG refrigerator, in which evaporator and capillary tube are the main component, an adequate physical design of ad sorter in small volume and light weight are priority .Operating parameters are considered during the design procedure but will be optimized later during experimental testing.

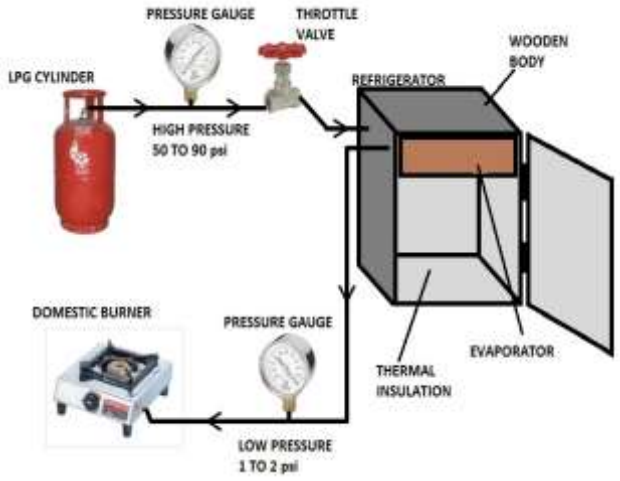

Fig. 5 LPG Refrigerator setup

LPG Gas Cylinder: LPG gas pressure is approximate 80-100 psi.LPG flows through high pressure pipe and reaches to the capillary tube from the LPG gas cylinder.

Capillary Tube: As the capillary tube, capillary tube drops the pressure up to less than 1 psi.

Evaporator: LPG is converted into the vapour from with low pressure in the evaporator. After flowing through the evaporator low pressure and temperature LPG vapour extract heat from the chamber system.

Gas Burner: Low pressure LPG gas goes into the burner to burns after performing the cooling effect.

Now there are two approaches to design.

i. Isenthalpic expansion, as shown by link k-a.

ii. Adiabatic or Fanno-line expansion, as shown by line k-b.

The steps of calculation

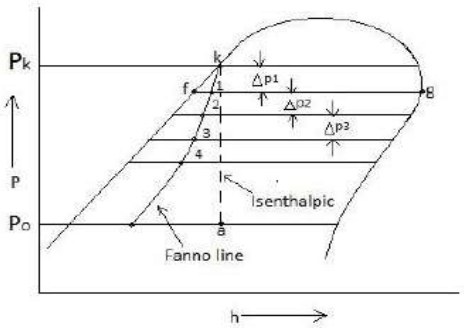

Fig. 6 Incremental pressure drops in a capillary tube

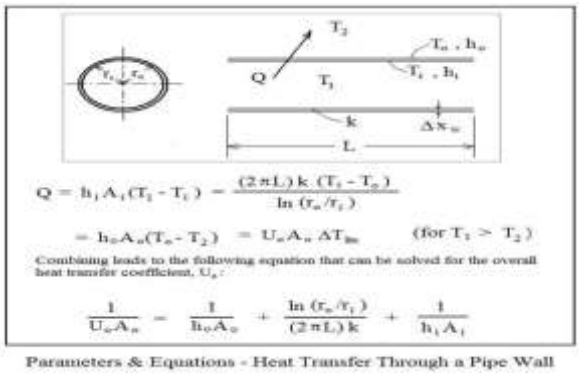

Fig. 7

Where,

Q= heat transfer
H=coefficient of heat transfer
A=area of tube
U=over all heat transfer coefficient
Ti= inlet temperature
To=outlet temperature

V. Working Principle And Process of LPG Refrigerator

LPG is extracted at high pressure in liquefied state from the storage device. Its pressure and flow rate is controlled by a valve connects it to the evaporator at requisite pressure in requisite quantity. An evaporator is housed through which LPG flows. It gets converted from liquefied state to gaseous state and expands. So it absorbs heat in the form of latent heat. Due to this process, heat from surrounding is absorbed so cooling effect is produced. This effect is magnified by an evaporator. A network of pipes containing gas is covered by thin and closely spaced fins which help in effective and fast cooling. The insulating material helps in storing the cooling effect for a longer period of time. The LPG leaves the evaporator in gaseous form; it is then directed towards the burner, engine, or any other application where it is to be used. Thus, no LPG is consumed for cooling purpose.

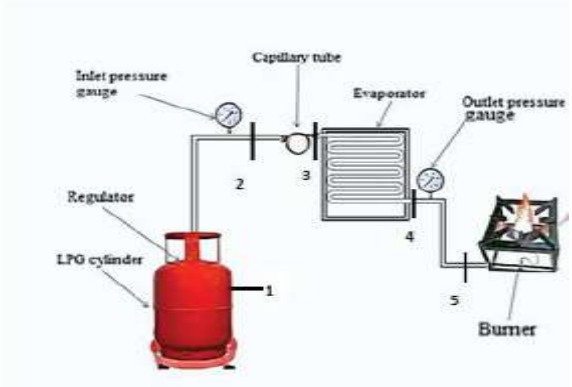

Fig. 8 block diagram

VI. Conclusion

The project "Analysis and performance of domestic refrigerator using LPG as refrigerant" is based on the principle of adiabatic expansion of a refrigerant (In this case LPG) from 80 psi to 10 psi so that thermodynamically it absorbs heat from surrounding and cooling may done. Expected cooling is predicted up to range of 20 to 50 degrees.

Using the sophisticated data and instruments the relevant refrigeration system will be develop practically. In this project the capillary tube is more suitable throttling device in LPG refrigeration system.

This system is cheaper in 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 is also very low. We also conclude that, we try the burnt to the exhaust LPG, as we daily do but also the refrigeration is obtained which is inherent process takes place daily. In this system this refrigeration is amplified remarkably and a cheaper and eco-friendly method is developed. This system most suitable for hotel, industries, refinery, chemical industries where consumption of LPG is very high.

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