Performance Analysis of Refrigeration System Using LPG as Refrigerant

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***Abstract*--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 locally available and comprises 24.4% propane, 56.4% butane and 17.2% isobutene which is very from company to company. The LPG is cheaper and possesses an environmental friendly nature with no ozone depletion potential (ODP). It is used in world for cooking purposes. The various methods of refrigeration on the basis of standard refrigerant discussed. He refrigerator used in the present study is of medium size with a gross capacity of 125 litre and 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 refrigerant instead of CFC 12. The evaporator temperature reached -5 ºC with and an ambient temperature of 12 ºC. 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 results of the present work indicate the successful use of this propane-butane mixture as an alternative refrigerant to CFC 12 in domestic refrigerant.**

Keywords— Refrigeration process, Temp. Zone and Rating , Refrigerant ,working and Analysis of LPG Refrigerator

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 ºC, 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 ºC. Thus in a refrigerator, heat is virtually being pumped from a lower temperature to a higher temperature. 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. Theoretically, the refrigerator is a reversed heat engine, or a heat pump which pumps heat from cold body and delivers to a hot body. 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.

II. REFRIGERATION PROCESS

Refrigerator: Refrigerator keeps things cold because of the nature of the heat. Thermodynamics essentially starts that if a cold object is placed to a next to a hot object, the cold object will become warmer and the hot object will become cooler. A refrigerator does not cool items by lowering their original temperature; instead, an evaporating gas called a refrigerant draws heat away, leaving the surrounding area much colder. Refrigerators and air conditioners both work on the principle of cooling through evaporation. A refrigerator consists of two storage compartment – one for frozen items and the other for items requiring refrigeration but no freezing. These compartment are surrounded by a series of heat-exchanging pipes. Near the bottom of the refrigerator unit is a heavy metal device called a compressor. The compressor is powered by an electric motor. More heat-exchanging pipes are coiled behind the refrigerator. Running through the entire system is pure ammonia, which evaporates at -27 ºF. this system is closed, which means nothing is lost or added while it is operating. Because liquid ammonia is a powerful chemical, a leaking refrigerator should be repaired or replaced immediately.

The refrigeration process begins with the compressor. Ammonia compressed until it becomes very hot from the increased pressure. This heated gas flows through the coils behind the refrigerator, which allows excess heat to be released into the surrounding air. This is why users sometimes fill warm air circulating around the fridge. Eventually the ammonia cools down to the point where it become a liquid. This liquid form of ammonia is then forced through a device called an expansion valve or capillary tube. Essentially, the expansion valve has a small opening or the capillary tube has a very small diameter of copper tube that the liquid ammonia is turned into a very cold, fast-moving mist, evaporating as it travels through the coils in the freezer.

As the evaporating ammonia gas absorbs more heat, its temperature rises. Coils surroundings the lower refrigerator compartment are not as compact. The cool ammonia still draws heat from the warmer objects in the fridge, but not as much as the freezer section. The ammonia gas is drawn back into the compressor, where the entire cycle of pressurization, cooling and evaporation begins anew.

Refrigeration Cycle: The refrigeration cycle uses a fluid, a called a refrigerant, to move heat from one place to other. We will begin with the cool, liquid refrigerant entering the indoor coil, operating as the evaporating during cooling. As the name implies, refrigerant in the evaporator "evaporator". Upon entering the evaporator, the liquid refrigerant's temperature is between 40 and 50 ºF and without changing its temperature, it absorbs heat as it changes state from a liquid to a vapour. The heat comes from the warm, moist room air blown across the evaporator coil. As it passes over the cool coil, it gives up some of its heat and moisture may condense from it. The cooler, drier room air is re-circulated by a blower into the space to be cooled. The vapour refrigerant now moves into the compressor, which is basically a pump that raises the pressure so it will move through the system. The increased pressure from the compressor causes the temperature of the refrigerant to rise. As it leaves the compressor, the refrigerant is a hot vapour, roughly 120 to 140 º F. It now flows into the refrigerant-to-water heat exchanger, operating as the condenser during the cooling. As it condenses, it gives up heat to the loop, which is circulated by a pump

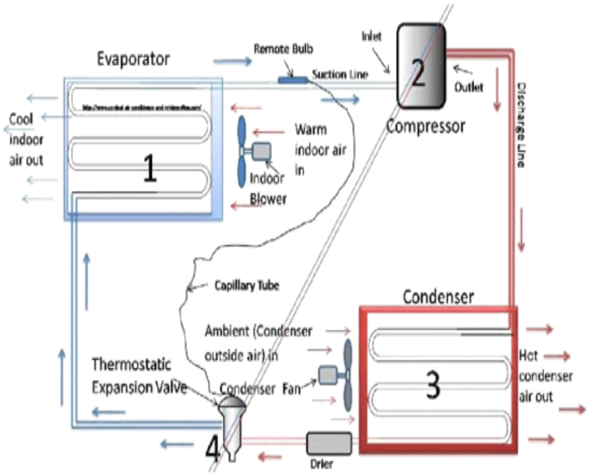


Fig 1.- Refrigeration Cycle

As the refrigerant leaves the condenser, it is cooler, but still under pressure provided by the compressor. It then reaches the expansion valve or capillary tube. That the high pressure refrigerant to "flash" through becoming a lower pressure, cooled liquid. When pressure is reduced, as with spraying an aerosol can or a fire extinguisher, it cools. The cycle is complete as the cool, liquid refrigerant re-enters evaporator to pick up room heat.

How Refrigerator Works: In the summertime, have you ever gotten out of a swimming pool and then felt very cold standing in the sun? that's because the water on your skin is evaporating. The air carries off the water vapour, and with it being taken away from your skin. This is similar to what happens inside older refrigerators. Instead of eater, through, the refrigerator uses chemicals to do the cooling.

There are two things that need to be known for refrigeration.

1) A gas cools on expansion.

2) When you have two things that are difference temperature that touch or are near each other, the hotter surface cools and the colder surface warms up. This is a law of physics called the Second Law of Thermodynamics.

TEMPERATURTE ZONE AND RATING: Some refrigerators are now divided into four zones to store different types of food:

1) -18 ºC (0 ºF) (freezer)

2) 0 ºC (32 ºF) (meats)

3) 5 ºC (49 ºF) (refrigerator)

4) 10 ºC (50 ºF) (vegetables)

The capacity of a refrigerator is measured in either litres or cubic feet (US). Typically the volume of a combined fridge-freezer is split to 100 litres (3.53 cubic feet) for the freezer and 140 litres (4.94 cubic feet) for the refrigerator, although these values are highly variable. Temperature settings for refrigerator and freezer compartments are often given arbitrary numbers (for example, 1 through 9, warmest to coldest) by manufacturers, but generally 2 to 8 ºC (36 to 46 ºF) is idle for the refrigerator compartment and -18 ºC (0 ºF) for the freezer. Some refrigerators require a certain external temperature 16 ºC (60 ºF) to run properly. Thus can be an issue when placing a refrigerator in an unfinished area such as a garage.

Refrigerant

Refrigeration application	Short Description	Typical HFCs
		used
Domestic Refrigeration	Appliances used for keeping food in	HFC-134a
	dwelling units.	
Commercial	Holding and displaying frozen and fresh	R 404A, R 507,
Refrigeration	food in retail outlets	HFC-234a
Food processing and cold	Equipment to preserve, process and store	R410A,
storage	food from its source to the wholesale	R407C,R 507,
	and cooling	HFC-134a
Industrial Refrigeration	Large equipment, typically 25 kW to	HFC-134a, R-

			30				
			MW, used for chemical processing, cold		404A, R-507		
			storage, food processing and district				
			heating and cooling				
	Transport refrigeration		Equipment to preserve and store goods,		R410A, R407C,		
			primarily foodstuffs, during transport by		HFC-134A		
			road, rail, air and sea				

Vapour Compression Cycle: The vapour compression cycle is the mostly widely used method of refrigeration in the modern application. Your household refrigerator, water cooler, deep freezer, air-conditioner etc, all run on vapour compression cycle. The cycle is called as vapour compression cycle, because the vapours of refrigerant are compressed in the compressor of the system to develop the cooling effect. The vapor-compression cycle is used in most household refrigerators as well as in many large commercial and industrial refrigeration systems. Figure 2 provides a schematic diagram of the components of a typical vapor-compression refrigeration system.

Working

Here are the various process of vapour compression cycle (refer the figure).

1) *Compression:* The vapours of refrigerants enter the compressor and get compressed to high pressure and high temperature. During this process the entropy of the refrigerant ideally remains constant and it leaves in superheated state.
2) *Condensation:* The superheated refrigerant then enters the condenser where it is cooled either by air or water due to which its temperature reduces, but pressure remains constant and it gets converted into liquid state.
3) *Expansion:* The liquid refrigerant then enters the expansion valve or throttling valve or capillary tube when sudden expansion of the refrigerant occurs, due to which its temperature and pressure falls down. The refrigerant leaves expansion valve or capillary tube in partially liquid state and partially in gaseous state.
4) *Evaporation or cooling*: The partially liquid and partially gaseous refrigerant at very low temperature enters the evaporator where the substance to be cooled is kept. It is here where the refrigeration effect is produced. The refrigerants absorbs the heat from the substance to be cooled and gets converted into vapour state.

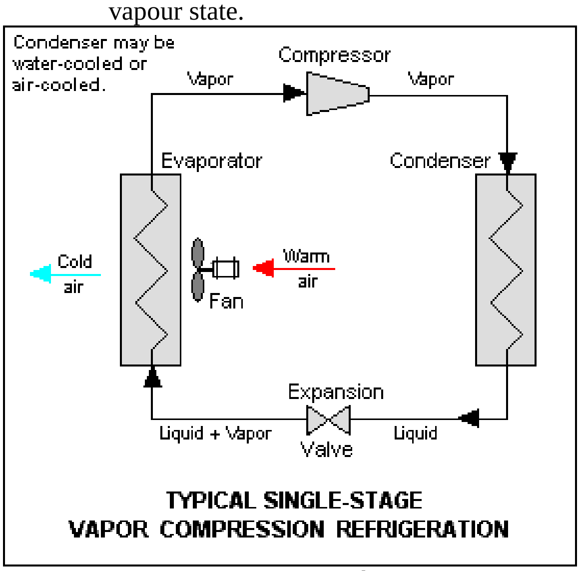


Fig 2: Vapour compreesion cycle

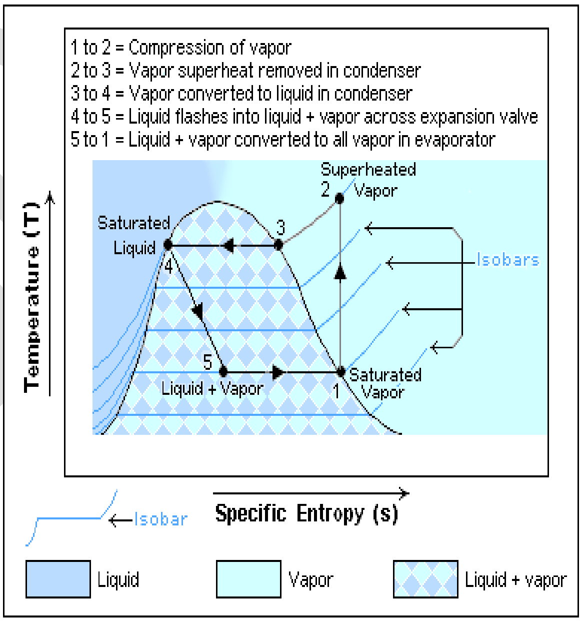


Fig 3: T-S diagram

Vapour Absorption Cycle: The various processes of the vapour absorption cycle are similar to the one in vapour compression cycle, only the method of compression of the refrigerant is different. In vapour absorption system ammonia is used as the refrigerant, which has very high affinity to dissolve in water. Here are various processes of vapour absorption cycle.

Principles: Absorptive refrigeration uses a source of heat to provide the energy needed to drive the cooling process.

The absorption cooling cycle can be described in three phases:

Evaporation: A liquid refrigerant evaporates in a low partial pressure environment, thus extracting heat from its surroundings – the refrigerator.

Absorption: The gaseous refrigerant is absorbed – dissolved into another liquid - reducing its partial pressure in the evaporator and allowing more liquid to evaporate.

Regeneration: The refrigerant-laden liquid is heated, causing the refrigerant to evaporate out. It is then condensed through a heat exchanger to replenish the supply of liquid refrigerant in the evaporator

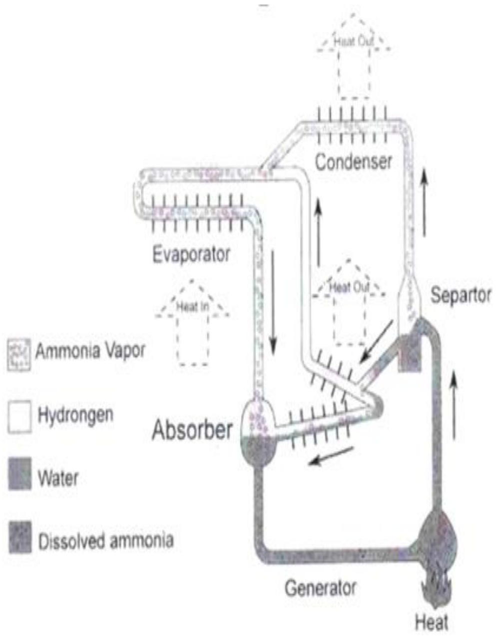


Fig.4 vapour absorption system

III. LPG REFRIGERATION

In India, more than 80% of the domestic refrigerator utilize 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 of assess various refrigerant option considering the existing refrigerators in the field and for the future market. CFC's are principally destroyed by ultraviolet radiations in the stratosphere; the chlorine released in the high stratosphere catalyzes the decomposition of ozone to oxygen; and ultraviolet radiations penetrates to lower altitudes. Credible calculations of the magnitude of the effect (Hoffman 1987) and his team predicted 3% global ozone emissions of 700 thousand tonnes/year after a hundred years. The ozone impact of car air conditioners also can not be ignored. Hydrofluorocarbons (HFC's) can be thought of as a replacement, but unfortunately the radiation properties of HFC's 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 serviceability 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. This hygroscopicity demands stringent service practices, which otherwise results in moisture entry into the system. Thus, hydrocarbon refrigerants; particularly LPG serves as the best contender to replace CFC's from domestic refrigerator as well as car air conditioners.

LPG consists mainly of propane (R-290) and butane (R-600), and LPG is available as a side product in local refineries. In Cuba for already several decades LPG is used as a drop-in refrigerant. LPG mixtures have composition of a commercial LPG mixture suitable as 'drop-in' replacement for R-12 was calculated crudely as 64% propane and 36% butane by mass. Liquefied petroleum gas (LPG) of 60% propane and 40% commercial butane has been tested as a drop-in suitable for R 134a in a single evaporator domestic refrigerator with a total volume of 10 ft3. The revival of LPG refrigerants in domestic and small commercial application in a happy accident (Vidal 1992). Engineers had known since the 1920's that LPG refrigerants performed well and in the 1980s refrigerators manufacturers again tested them (Kuijpers et al. 1988). Fear of a flammability campaign from the chemical industry deterred any manufacture.

In march 1989, the Institute of Hygiene in Dortmund Germany needed a new cold storage room. The young idealistic director, Dr Harry Rosin, could not consider using a CFC refrigerant and so tried propane and iso butane.

Greenpeace Australia imported a Foron refrigerator in February 1993 and in December 1993 Email Ltd, Australia's largest appliance manufacturer, displayed prototype LPG refrigerators. In 1994, German manufacturer announced one by one their intention of switch to LPG refrigerants. OZ Technology Inc, a start up company in Idaho, introduced OZ-12 a mixture of commercial propane and butane in 1992. they sold over 50,000 170 g cans the first summer. The Mobile Air-Conditioning Society made flammability hazard claims including 'a bomb in the passenger compartment' (Keebler 1993, MACS 1993). The US EPA refused to approve OZ-12 on flammability grounds. OZ then introduced another LPG refrigerant HC-12a, which has already sold over 100,000 cans. The US EPA may not approve this either but OZ's petition (OZ 1994) is convincing, comprehensive and technically sound especially on safety. Calor released Care 30 in June 1994. Care 30 is a high purity mixture of R-290 and R-600a and is a drop- in replacement for R-12 and R 134a. it has been very successful in vehicle refrigeration and air-conditioning.

IV. CONSTRUCTION OF THE LPG REFRIGERATOR

The LPG refrigerator shown in figure. We make the one box of the plywood. The plywood sheet size is 12mm for used the LPG refrigerator. The size of the refrigerator is 724*457*381 mm3. The evaporator is fitted on the upper portion of box inside. Inside the refrigerator, we also put the thermo-coal sheet; because of the cold air can not the transfer from inside to outside of refrigerator.

Fig .5 Construction of LPG Refrigerator

The schematically diagram of the LPG refrigeration system is shown in next page. The gas tank is connect by pipes to the capillary tube. The capillary tube is fitted with evaporator. The evaporator coiled end is connect to the stove by another gas circulation pipe. When two pressure gauge is put between capillary tube and gas tank, and another is put the end of the evaporator.

V. WORKING LPG REFRIGERATOR

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

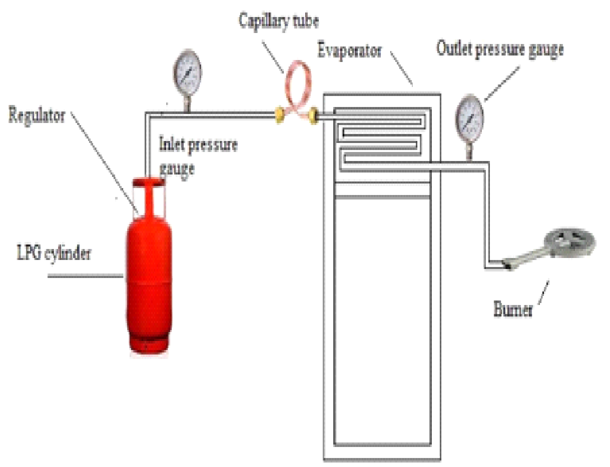


Fig. 6 Working of LPG Refrigerator

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 is going by high pressure gas pipe in capillary tube. High pressure LPG is converted in low pressure at capillary tube with enthalpy remains constant. After capillary tube, low pressure LPG is passed through evaporator. LPG is converted into low pressure and temperature vapour from and passing through the evaporator which absorbs heat from the chamber. Thus the camber becomes cools down. Thus we can achieve cooling effect in refrigerator. After passing through the evaporator low pressure LPG is passed through pipe by burner. And we can uses the low pressure of LPG is burning processes.

VI. CAUSES AND PRECAUTION

Explosion in space any refrigerant with vapour pressure above ambient can flash to a larger volume. The potential increase in volume is greater if combustion of lubricant or refrigerant occurs. Explosion venting may be necessary to limit pressure rise to what the space can safely withstand. 2 kPa can blow window glass off a building.

Fire Combustible lubricant and refrigerant must be discharged safely outside a building when a fire occurs especially it the heat of combustion exceeds 200 MJ.

Asphyxiation or poisoning All refrigerants except air and oxygen are asphyxiations. Ventilation must prevent serious injury or death on a sudden total release of refrigerants. The quantity of ventilation necessary varies greatly between refrigerants. Flying metal System must comply with piping and pressure vessels codes.

Corrosion or chemical reaction LPG refrigerants are non-reactive and chemically stable at refrigeration temperature. Chemical or cold burns Accidental contact between skin and cold metal must be prevented by insulation. Accidental releases of liquid refrigerant must drain safely.

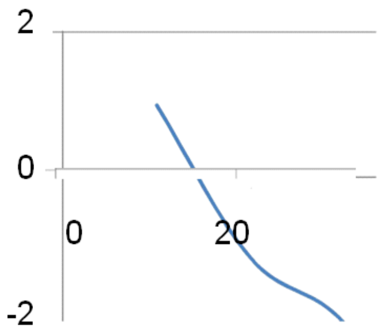
VII. ANALYSIS OF LPG REFRIGERATOR

- Size of Refrigerator :-724*457*381 mm3
- Atmospheric temperature :- 40 ºC
- Initial water temperature :- 35 ºC
- Inlet pressure of LPG :-80 psi
- Outlet pressure of LPG :- less than 1psi

Observation Table And Chart: The experiment of this project was done on June 25, 2014 at 1.45p.m. and reading were taken under ten minute's interval which are under as follow:

Time	Pressure in bar	Inlet Temp. (ºC)	Outlet Temp. (ºC)	Water Temp. (ºC)	Freezer Temp. (ºC)	Chamber Temp. (ºC)
10	6.7	0.2	10	30.0	1.0	37.9
10	6.4	0.01	8.2	24.2	-1.1	33.8
10	6.8	-0.09	7.6	19.7	-2.0	29.4
10	6.7	-0.90	5.2	15.8	-4.1	25.5
10	6.6	-1.25	4.1	11.2	-6.0	23.1
10	6.7	-2.20	3.1	8.3	-6.9	19.9
10	6.7	-3.74	2.2	5.1	-7.5	17.9
10	6.8	-4.90	1.8	3.2	-7.9	15.7
10	6.6	-5.90	1.1	1.02	-8.9	14.2
10	6.7	-7.10	0.5	0.30	-9.3	10.3

Chart :- Freezer Temperature Vs Time Period
X axes : Time Period in minute.
Y axes : Freezer surface temperature in ºC.



CONCLUSION

After performing this project "LPG Refrigeration", we conclude that refrigeration effect is produced with the use of LPG. From observation table, we conclude that, the regulating valve is fully open that, we achieve the chamber temperature down from 38ºC to 10ºC in a 100 minute. We achieve the evaporator temperature down from 1ºC to -9.3ºC in a same time interval. We put the water in one plastic bottle in the evaporator. The initial temperature of water is 35 ºC. From observation table, we conclude that, the condition of regulating valve is fully opened, the same time period we achieve the temperature of water is 0.30 ºC. We also conclude that, the capillary tube is maximum pressure of gas cylinder is reduces the less then of 1 psi. 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, the pressure of exhaust gas is less than 1 psi, the small flame produce by the burner. This system most suitable for hotel, industries, refinery, chemical industries where consumption of LPG is very high.

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