ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Refrigeration System by Using LPG (Liquefied Petroleum Gas)

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Abstract:
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. 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.

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.

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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.

II. TYPES OF REFRIGERATION:

The different types of refrigeration systems are given below.

Cyclic Refrigeration:

In the cyclic process of refrigeration the heat is removed from the low temperature reservoir and is thrown to high temperature. As per the second law of thermodynamics the natural flow of heat is from high temperature to low temperature reservoir. In the cyclic refrigeration process since the flow of heat is reserved, the external work has to be done on the system.

The cyclic process of refrigeration is also reverse of the thermodynamic power cycle or Carnot cycle in which the heat flows from high temperature reservoir to low temperature reservoir. Hence the cycle of refrigeration is also called as Reversed Carnot Cycle. There are two types of cyclic process of refrigeration: Vapor cycle and Gas cycle.

Vapor Cycle:

It is classifies into 2 types: Vapor compression cycle and Vapor absorption cycle.

Vapor Compression Cycle:

In vapor compression system, an evaporator and a gas-liquid separator are received in a common casing, so that the gas-liquid separator and the evaporator are placed close to each other. Thus, it is possible to limit heat absorption of the liquid phase refrigerant from the atmosphere to reduce the heat loss upon discharge of the refrigerant from the gas-liquid separator. Also, it is possible to reduce pressure loss in refrigerant passage between the gas liquid separator and the evaporator.

Vapor Absorption Cycle:

Before the development of the vapor compression system of refrigeration, vapor absorption system was very widely used. The vapor compression system replaced vapor absorption system because it has high coefficient of performance (COP). The vapor absorption system requires very less amount of electricity but large amount of heat; hence it can be used very effectively in industries where very large stocks of excessive stem are available. In such cases there is not only effective utilization of steam, but also lots of savings in electricity costs.

Gas Cycle:

Just as vapor is used for cooling in the vapor compression cycle and vapor absorption cycle, gas is used in gas refrigeration cycle. When gas is throttled from very high pressure to lower pressure in throttling valve, its temperature reduces suddenly while its enthalpy remains constant. This principle is in gas refrigeration system. In the system instead of using Freon or ammonia as the refrigerant, the gas is used as the refrigerant. Throughout the cycle there are no phase changes of the gas, which are observed in the liquid refrigerant. Air is the most commonly used gas, also called as refrigerant in this gas refrigeration cycles.

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Non Cyclic Refrigeration:

In these methods, refrigeration can be accomplished by melting ice or by dry ice. Because we are not using refrigerant gain don't require any compressor to compress the refrigerant in all the cases as in cyclic refrigeration. These methods are used for small-scale refrigeration such as in laboratories and workshops, or in portable coolers. This type of refrigeration find in aircraft refrigeration purpose because as aircraft moves forward air enters and leaves the system fast. So we can make use of this in non-cyclic refrigeration where refrigerant is available abundant at free of cost.

Vapor Compression Cycle:

The vapor compression cycle is the most widely used method of refrigeration in the modern application. Your household refrigerator, water cooler, deep freezer, air-conditioner etc., all run on vapor compression cycle. The cycle is called as vapor compression cycle, because the vapors of refrigerant are compressed in the compressor of the system to develop the cooling effect.

III. WORKING

Compression:

The vapors 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.

Condensation:

The superheated refrigerant then enters the condenser where it is cooled eitherby air or water due to which its temperature reduces, but pressure remains constant and gets converted into liquid state.

Expansion:

The liquid refrigerant then enters the expansion 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.

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 refrigerant absorbs the heat from the substance to be cooled and gets converted into vapor state.

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

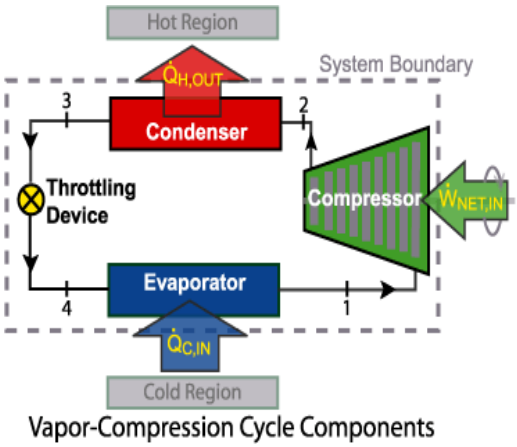

Fig 1: VCR system

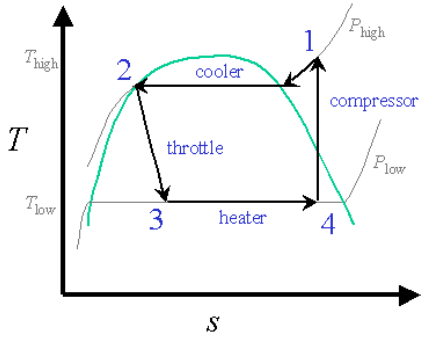

Fig 2: T-S diagram of VCR system

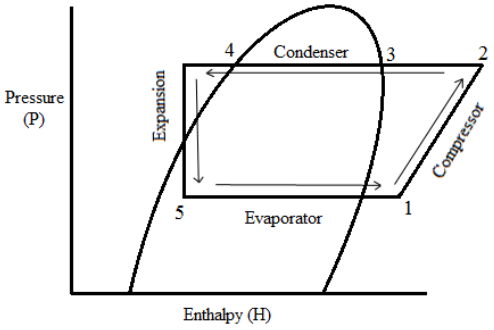

Fig 3: P-H diagram of VCR system

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Advantages of VCR:

- » Large amount of refrigeration at lower initial purchase and operating cost.
- » Very efficient
- » Very compact system for small to very large heat loads.
- » Cycle can be reversed for heat pump operation.

Disadvantages of VCR:

- » Parts can wear out.
- » Noise
- » Potential refrigerant leaks.
- » Operates in limited orientation.

Applications of VCR:

- » Household refrigerator,
- » Air conditioners,
- » Water coolers,
- » Ice and Ice cream makers,
- » Deep freezers,
- » Large industrial refrigeration and
- » Air conditioning systems.

Temperature Zone and Rating:

Some refrigerators are now divided into four zones to store different types of food:

- -18 °C (0 °F) (freezer)
- 0 °C (32 °F) (meat zone)
- 5 °C (41 °F) (cooling zone)
- 10 °C (50 °F) (crisper)

The capacity of a refrigerator is measured in either liters or cubic feet. Typically the volume of a combined refrigerator-freezer is split to 100 liters (3.53 cubic feet) for the freezer and 140 liters (4.94 cubic feet) for the refrigerator,although these values are highly variable.

IV. Fundamentals of Refrigeration

Refrigeration and Second Law of Thermodynamics

Refrigeration is the removal of heat from a space at a temperature lower than the surrounding temperature.

Due to the natural frequency of heat to flow from higher to lower temperature, the rushes to replace the heat removed. But a refrigerator rejects the heat that is entering into the system back to the atmosphere. Hence input of work is essential, according to second law of thermodynamics systems for pumping heat from lower to higher temperatures.

Units of Refrigeration:

A unit is used in the field of refrigeration is known as Ton of Refrigeration. A Ton of Refrigeration is defined as the quantity of the heat required to be required to be removed from one ton of ice within 24 hours when the initial condition of water is 0 °C, because same cooling effect will be given by melting the same ice.

Methods of Refrigeration

Ice Refrigeration

The science of refrigeration utilizes several methods of providing temperature differential. In all types of refrigeration systems, some physical property of matter is used cold temperature. The different methods of refrigeration and its working principle are discussed below.

Evaporation Refrigeration:

In this method, the ice is placed at the top of the insulated cabin and the shelves for food are located below the ice compartment. Cold air flows downwards from the ice compartment and cools the food on the shelves below it. Temperature achieved in the method ranges between 5 °C to 10 °C.

Refrigeration by Expansion of Air:

In this method, the temperature of gas is reduced by an adiabatic expansion of the gas. It is universally used for producing low temperatures in all air refrigeration systems.

Vapor Refrigeration Systems:

In Vapor refrigeration systems, instead of air, vapors like ammonia, carbon dioxide, are used as working fluids.

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It is extensively used in steam power plant. In this system, heat carried away by the Vapor in the refrigeration per kg of refrigerant is far then the air refrigeration systems.

Steam Jet Refrigeration Systems:

Water is the refrigerant here. This uses the principle that boiling temperature of water decreases, if the pressure on the surface of water is reduced. This reduction in pressure is maintained by throttling the steam through the nozzles. When certain amount of water boils, the subsequent amount of heat is removed from water resulting in lowering the temperature of water. This system is used almost excessively for comfort in air conditioning installation.

Dry Ice Refrigeration:

Dry ice is solid carbon dioxide. The property of dry ice to change directly from solid to vapor state is used for maintaining low temperature. Dry ice is usually packed in frozen food cartons. Dry ice, as it changes to a vapor, keeps the food frozen.

V. REFRIGERANTS:

The thermodynamic efficiency of refrigeration system mainly depends on its operating temperatures. However, important practical issues such as system design, size, initial and operating costs, safety, and serviceability etc.; depend very much on the type of the refrigerant selected for given application. Due to several environmental issued such as ozone layer depletion and global warming and their relation to the refrigerants used, the selection of suitable refrigerant has become one of the important issues in recent times.

Replacement of an existing refrigerant by a completely new refrigerant, for whatever reason, is an expensive proposition as it may call for several changes in the design and manufacturing of refrigeration systems. Hence it is very important to understand the issues related to the selection and the use of refrigerants. In principle, any fluid can be used as a refrigerant in vapor compression refrigeration systems only.

Primary and Secondary Refrigerants:

Fluids suitable for refrigeration purpose can be classified into primary and secondary refrigerants. Primary refrigerants are those fluids, which are used directly as working fluids, for example in vapor compression and vapor compression refrigeration systems. When used in compression or absorption systems, these fluids provide refrigeration by undergoing phase changing process in the evaporator. As the name implies, secondary refrigerants are those fluids, which are used for transporting thermal energy from one location to other. Secondary refrigerants are also known under the name brines or antifreezes. Of course, if the operating temperatures are above $0^{o}C$, then pure air blower can also be used as secondary refrigerant, for example in large air conditioning systems. The secondary refrigerants do not undergo phase change as they transport energy from one location to other.

An important property of secondary refrigerant is its freezing point. Generally, the freezing point of brine will be lower than the freezing point of its constituents. The temperature at which the freezing point of brine takes place depends on its concentration. The concentration at which a lowest temperature can be reached without solidification is called as eutectic point. The commonly used secondary refrigerants are the solution of air blower and ethylene glycol, propylene glycol or calcium chloride. These solutions are known under the general name of brines. In vapor absorption system, a refrigerant and absorbent combination is used as the working fluid.

Refrigerant Selection Criteria:

Selection of refrigeration for a particular application is based on the following requirements

- Thermodynamic and thermo physical properties
- Environmental and safety properties, and
- Economics

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Thermodynamics and Thermo Physical Properties

The requirements are:

- Suction pressure: At a given evaporated temperature, the saturation pressure should be above atmospheric for prevention of air or moisture ingress into the system and case of leak detection. Higher suction pressure is better as it leads to smaller compressor and displacement.
- Discharge pressure: At a given condenser temperature, the discharge pressure should be as small as possible to allow light weight construction of compressor, condenser etc.
- Pressure ration: Should be as small as possible for the high volumetric efficiency as low power consumption.
- Latent and heat of vaporization: Should be as large as large possible so that the required mass flow rate per unit cooling capacity will be small.

Environmental and Safety Properties:

Next to the thermodynamic and thermos physical properties, the environmental and safety properties are very important. In fact, at the present the environment friendliness of the refrigerant is a major factor in deciding the usefulness of a particular refrigerant. The important environmental safety properties are:

VI. 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.

Properties of LPG:

- Colorless.
- Odorless (It's normal to odorize LPG by adding an odorant prior to supply to the user, to the aid detection of any leaks).
- Heavier than air.
- Liquid LPG is half the weight of water.
- Non-toxic.
- LPG expands upon release and 1 liter of liquid will form approximately 250 liters of Vapor.

LPG Refrigeration Cycle

LPG Gas Cylinder

From the LPG gas cylinder, LPG flows through the pipe and reaches to the capillary tube. LPG gas pressure is approximate 10 bars. In LPG cylinder gas is stored at 12.7 bars. By using a high pressure regulator LPG is sent to capillary tube using steel reinforced high pressure pipes.

Capillary Tube

At the capillary tube pressure drop takes place from 10 bar to 3 bar. For that pressure drop to take place a suitable dimension capillary tube is selected.

Evaporator

In the evaporator LPG is converted into the vapor form with low pressure. After passing through the evaporator low pressure and temperature LPG vapor absorbs heat from the chamber system and required cooling effect is produced in the evaporator.

GAS BURNER

After performing the cooling effect low pressure LPG goes into the burner where burning takes place.

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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.

Fig 4: 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.

Fig 5: Capillary tube

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.

Fig 6: Evaporator

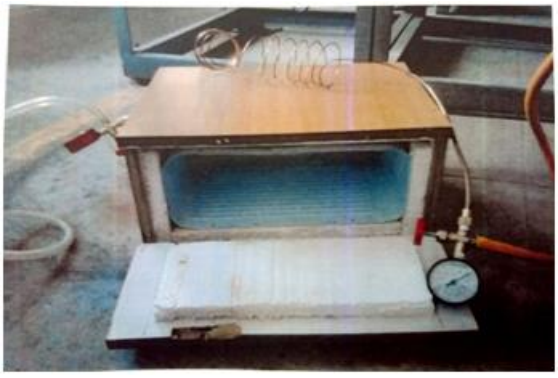

Fig 7: Evaporator with insulation

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.

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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.

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 8: 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 swiveling connection nipples press these balls against the seating of the connecting hole and thus sealing against gas leakage.
Wide range of pipes All pipes are pressure tested to 100 M Pa(14,500 psi) over recommended working pressure.

Fig 9: High pressure pipes

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 10: High pressure regulators

Construction ofLPG 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 11: LPG refrigeration and heating system

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VII. 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.

- 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.
- High pressure LPG is converted in low pressure at capillary tube with enthalpy remains constant.
- 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.
- 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.

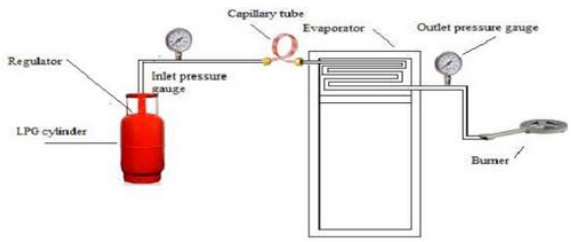

Fig 12: LPG refrigeration and heating system

Advantages of LPG Refrigeration System:

- Use of LPG as a refrigerant also improves the overall efficiency of by 10 to 20%.
- 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.
- A part from environment friendly, use of LPG also gives us lot of cost advantages.
- LPG does not form acids and there by eliminates the problem with blocked capillaries.
- There is 60% reduction in weight of the system due to higher density of LPG.
- This fridge works when electricity is off.
- The parts are effectively silent in operation.
- Running cost is zero
- Eliminates the compressor and condenser.

Application of LPG Refrigeration System:

- It can play an important role in restaurants where continuously cooling and heating is required.
- It can be used in chemical industries for refrigeration purpose.
- It can be useful in remote parts where electricity is not available.
- It can be used in refineries where consumption of LPG is high.

Results verification:

Time (in min)	Capillary inlet pressure (in bar)	Evaporator outlet pressure (in bar)	Evaporator temp (in °C)
0	10	3	35
5	10	3	27
10	10	3	19
15	10	3	13
20	10	3	5
25	10	3	5
30	10	3	5
35	10	3	5

VIII. CONCLUSION:

After performing this project "LPG REFRIGERATION", it is concluded that refrigerating effect is produced with the use of LPG. From observation table, It is concluded that, when the regulating valve is fully open then the evaporator temperature downs from 35°C to 5°C in 30 minutes. It is also concluded that, in the capillary tube pressure of gas 10 bar from the cylinder is reduced to 3 bar. The capillary tube is more suitable throttling device in LPG refrigeration system.

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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.

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