Using Liquefied Petroleum Gas (LPG) as an Environmentally Friendly Alternative Refrigerant

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Abstract- The biggest global issue currently is global warming and ozone layer depletion is one the reasons behind this. The domestic refrigerators are consuming millions of tons of chlorofluorocarbons and hydrofluorocarbons as refrigerants and damaging the environment through the ozone layer depletion. In current research the use of Liquified Pressurized Gas (LPG) as a refrigerant is experimentally investigated for refrigeration purpose. The LPG comprises of a mixture of 56% butane, 25% propane and approximately 17% iso-butane. It is economical, easily available, eco-friendly in nature and produces cooling effect in less time. The high-pressure LPG is stored in cylinder, and it is passed through the capillary tube of small diameter and large length, then it goes to evaporator and phase change of LPG occurs from liquid to gas through expansion process. Due to phase change from liquid to gas latent heat of evaporation is gained by the liquid refrigerant and the temperature decreased and LPG produces cooling effect in the surrounding environment.

Keywords- Liquefied petroleum gas; Chlorofluorocarbon; Hydrofluorocarbon; Ozone layer depletion; Global warming

I. INTRODUCTION

Domestic refrigerator is one of such appliances that runs throughout the year. The refrigerator consumes thousands of tons of conventional refrigerants like hydrofluorocarbons and chlorofluorocarbons each year. This consumption significantly contributes to ozone layer depletion and global warming.

Refrigerators are widely used in houses, hotels, shopping malls as well as in the chemical and pharmaceutical industry. To reduce the capital cost of refrigeration and to make a much more efficient system a continuous cooling effect is required. That in turn will continuously deplete the ozone layer and eventually resulting in global warming. Many researchers have worked on finding the suitable and more environmentally friendly alternatives for the traditional refrigerants having low global warming potential (GWP) and low ozone depletion potential (ODP) [1]–[4].

The alternative to chlorofluorocarbons as a refrigerant were investigated and the mixture of R600a, and R406a was compared to R-12 in terms of performance and service. It was concluded that R406a and R600a when mixed in 9:11 ratio can be a better alternative of R-12 for domestic refrigerators with better coefficient of performance (COP) [5]. The refrigerants having zero ODP and low GWP were studied, and it was found that using mixture of hydrofluorocarbons (HFCs) and hydrofluoroolefins (HFOs) can be used as environmentally friendly alternative to the refrigerants already used in domestic refrigeration systems [6]. It was also reported that the mixtures of traditional refrigerants with hydrocarbons (HCs) are very promising alternatives for domestic refrigerators as they are more efficient and environmentally friendly. The HFC and HC mixed refrigerants has a low global warming potential that falls within the permissible limits. They also provide low energy consumption, higher COP as compared to conventional refrigerants [7], [8]. Liquefied Petroleum Gases (LPG) is comprised of hydrocarbons and normally contains propane and butane as major constituents along with small amounts of some other hydrocarbons. LPG is basically an alternate domestic cooking fuel. In Pakistan the LPG is being produced and provided by the oil refineries that are producing LPG as their by-product and by the Gas and Oil exploration companies that are producing the LPG at their exploration sites. Major advantages of using LPG as an alternative refrigerant were reported that includes the zero ODP, very low GWP, higher COP, lower cost and better efficiency. These findings make LPG a very good contender to be used as a refrigerant in domestic refrigerators [9]–[11].

Fatouh, M et.al., [12] reported the use of LPG (40% Butane and 60% Propane) as alternate refrigerant over R134a and found that the LPG refrigerator has lower pressure ratio, pull-down time, and power consumption. LPG when used as refrigerant produces refrigerating effect through isenthalpic process as its phase changes from liquid to gas during expansion. The energy from LPG due to its high pressure was utilized to produce cooling effect and it is more efficient as compared to ordinary refrigerant [13]. The use of LPG as a refrigerant in domestic and automotive air conditioning system was also studied and it proved to be equally effective as other refrigerants and more eco-friendly [14].

In the current study the LPG is used as refrigerant in an experimental setup of domestic refrigerator where the cooling effect of LPG occur due to its phase change from the liquid state of gaseous state because of sudden expansion. The LPG was also used for burning purposes after being used in refrigerator.

II. Experimental Setup

The various components of the LPG refrigerator were designed, and CAD model of LPG refrigerator is presented in figure 1.

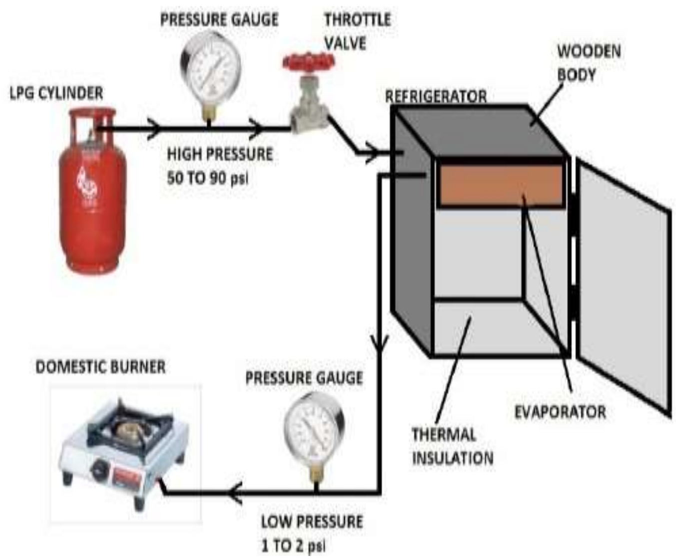


Figure 1: CAD model of LPG refrigerator

LPG was stored in a domestic LPG cylinder, which is a high-pressure vessel. A Regulator was used to control the pressure of LPG coming from cylinder. The regulator should be there to deliver a steady pressure. The high-pressure pipes are used for LPG to prevent leakage. Bourdon type pressure gauge was used in this setup to measure the LPG pressure coming from the cylinder. A dryer is used to remove the moisture from the refrigerant. The moisture can freeze inside the tube which can be a cause of restriction to flow of refrigerant that's why it is necessary to remove the moisture. Liquid line drier is placed before the capillary tube. The liquid refrigerant is filtered through the dryer before entering the capillary tube which prevents chocking.

The capillary tube was used in this setup which acts as a throttling device. It is made up of copper and it has small-bore diameter. The pressure of refrigerant will decrease, and its phase will change from liquid to gas as it passes through capillary tube to the evaporator. The internal diameter of the capillary tube usually varies from 0.5mm to 2.28 mm. In this setup the diameter of capillary tube is 1 mm, and it has a length of 10 feet.

The refrigerant then pass through the evaporator coil and cooling effect is produced inside the evaporator. The heat is removed from the substance because the coil achieves very low temperature, and the heat of substance is transferred to the refrigerant which has low temperature. Thus, the evaporator acts as heat exchanger. After producing the cooling effect, the low-pressure LPG burns in the burner from where we receive heat and can perform different functions like cooking etc. The actual LPG refrigerator setup used for this study is shown in figure 2.

Figure 2: Actual experimental setup of LPG refrigerator

III. Working Principle of LPG Refrigerator

The basic purpose of LPG refrigerator is to use LPG to absorb heat in evaporator from chamber. In this refrigeration system the refrigerant LPG (Liquefied Pressurized Gas) stored in the cylinder has a very high pressure. Pressure regulator is placed on the cylinder. By this regulator we can maintain the required pressure. When we open the regulator the liquid form of refrigerant flow through the high-pressure pipe and the pressure at the high-pressure gauge increasing and reach at the value which we require. Then liquefied refrigerant come in the liquid line dryer where moisture and other unnecessary contaminants are filtered, and pure refrigerant come out from dryer and pass through the capillary tube. Capillary tube has very small-bore diameter and its length is large. It reduces the pressure of refrigerant which passes through it and the refrigerant changes its phase from liquid to gaseous form and pass through the evaporator. So, the temperature of evaporator coil decreases because the refrigerant expands here, and cooling effect produced in evaporator. The heat of the substance to be cooled is transferred to the low pressure and low temperature refrigerant. This low-pressure refrigerant come out from the evaporator after receiving the heat from chamber (LPG gaseous form) and passed to the burner for burning process.

IV. Results and discussions

The variation in inlet pressure, outlet pressure, evaporator temperature and water temperature with respect to time was observed in this study. Initially, the inlet pressure of LPG was set at 40psi or 2.758 Bar and change in evaporation temperature with time was observed at this inlet pressure.

The figure 3 shows the change in evaporator's temperature with respect to time at 40 psi inlet pressure. The system worked for 40 minutes. Initially the temperature of evaporator is 26 degrees Celsius and it decreases gradually, after 40 minutes it reaches at -10 degree Celsius as shown in figure it is an effective result.

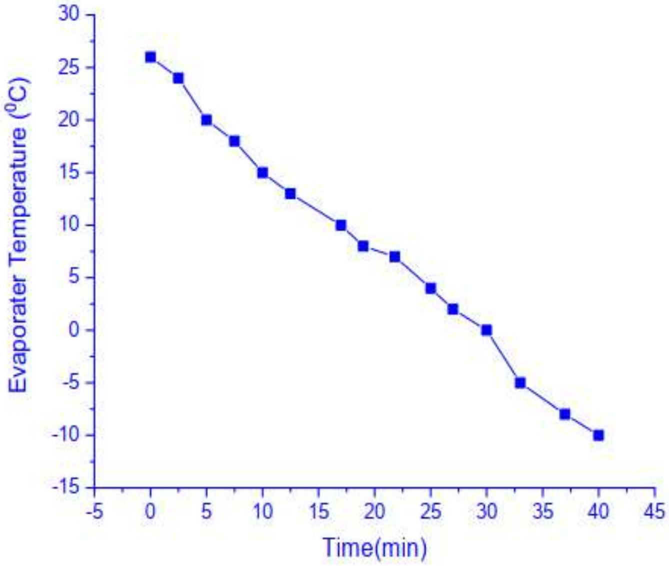


Figure 3: Variation of evaporator temperature at 40 Psi

The change in inlet pressure with respect to time was also plotted and it can be observed (see figure 4) that while cooling effect is produced and temperature is decreased the pressure also decreases. The equipment was started at 2.758 bar inlet pressure, and it drops to 2.143 Bar in 40 minutes. Thus, due to expansion the pressure drops, and cooling effect is produced.

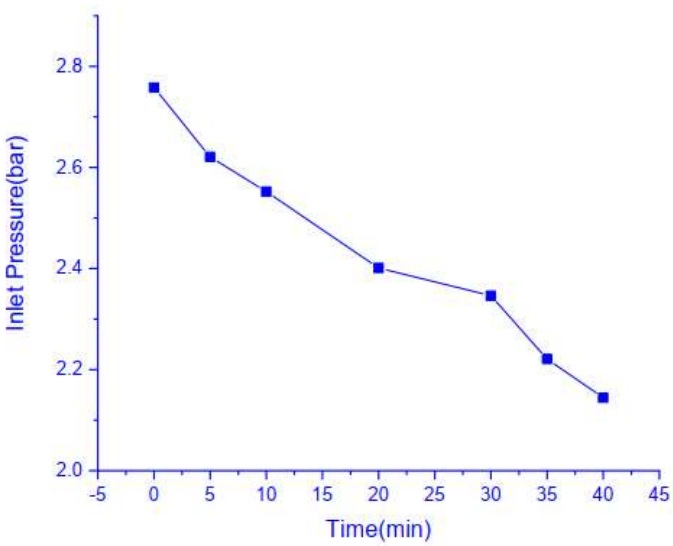


Figure 4: Variation of inlet pressure with time

The temperature of water placed in chamber varies with time. The temperature of water is 27 degrees Celsius when we the system started its working, and it decreases to 3 degrees Celsius in 40 minutes. The temperature drop depends upon evaporator performance. The temperature of water was also recorded with time and presented in figure 5.

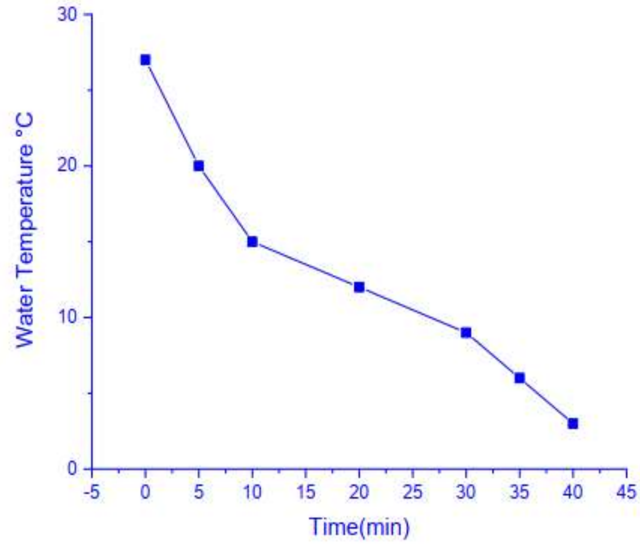
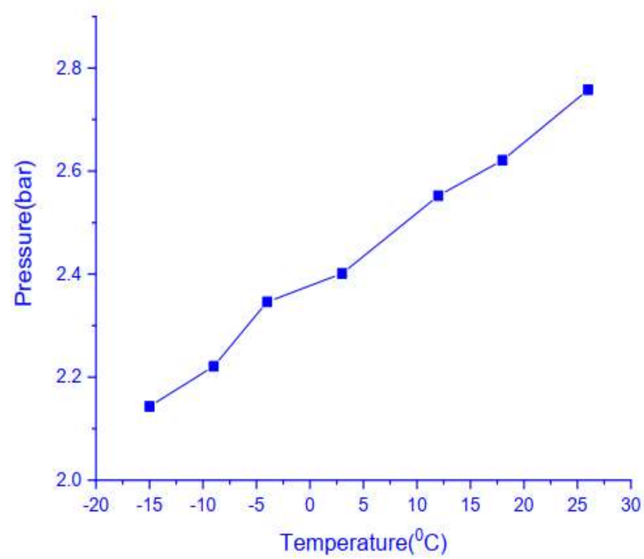


Figure 5: Variation of water temperature with time

Figure 6 shows the change in pressure with time. It is evident from the figure that when the system was started the temperature was 26 degrees Celsius and at this temperature pressure was 2.758 Bar. The pressure drops while LPG passed through the capillary tube, the temperature also starts to decrease and eventually reaches at -10 degree Celsius with pressure reduced to 2.143 Bar.



V. CONCLUSION

It can be concluded that efficient cooling effect by using LPG as a refrigerant can be achieved. The following remarks can be drawn:

- Capillary tube reduces the pressure of LPG coming from cylinder i.e., from 10 bar to 1-2 bar, where phase change occurs, and cooling effect is produced in evaporator.
- This system works on the principle of adiabatic enlargement of LPG (refrigerant).

- Initial cost of this system is cheap than others and running cost of this system is also very low. Because this system utilizes cooling effect of LPG and also use it for burning purpose.
- In LPG refrigeration system there is no moving part present so there is no wear and tear which makes its maintenance cost very low.
- This refrigeration system is very economical because our desired cooling e.g., up to -9℃ evaporator’s temperature can be achieved in very low cost. This refrigerant has zero ozone depletion potential (ODP), and global warming potential (GWP) for this refrigerant is also negligible.
- This technique is most suitable for the large buildings, hotels, and pharmaceutical industries etc. where the usage of liquefied petroleum gas is so high.

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