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Design and Fabrication of LPG Refrigerator

Mohd Ahmad[1], Yash Kasare[2], Tejas Somkuwar[3], Aishwarya Patil[4], Hakimuddin Husain[5], M. Nematullah Nasim[6]
[1,2,3,4]Students Department of Mechanical Engineering
[5,6]Professors, Department of Mechanical Engineering
Anjuman College of Engineering and Technology, Nagpur, India

Abstract: *This study is based on experimental observations aimed at evaluating the coefficient of performance (COP) of a refrigeration system using liquefied petroleum gas (LPG) as a refrigerant. The LPG composition used in this experiment consists of 56.5% butane, 24.4% propane, and 17.2% isobutene. The focus of the research is to analyze how variations in the length of the capillary tube affect the system's COP. LPG is a cost-effective and environmentally friendly alternative to conventional refrigerants. Its use helps in reducing the global warming potential (GWP) and has negligible ozone depletion potential (ODP), making it a sustainable option. Since LPG is abundantly available as a byproduct in oil refineries, it serves as a practical refrigerant for widespread use. By modifying and optimizing key components such as the regulating valve and capillary tube under suitable operating conditions, it is possible to achieve improved cooling performance. The experimental setup demonstrated that the evaporator temperature gradually decreased over time, eventually reaching a minimum of 5 ℃, indicating effective cooling performance using LPG as a refrigerant.*

Keywords: LPG refrigerant, refrigeration effect, household kitchen, COP, environment friendly

I. INTRODUCTION

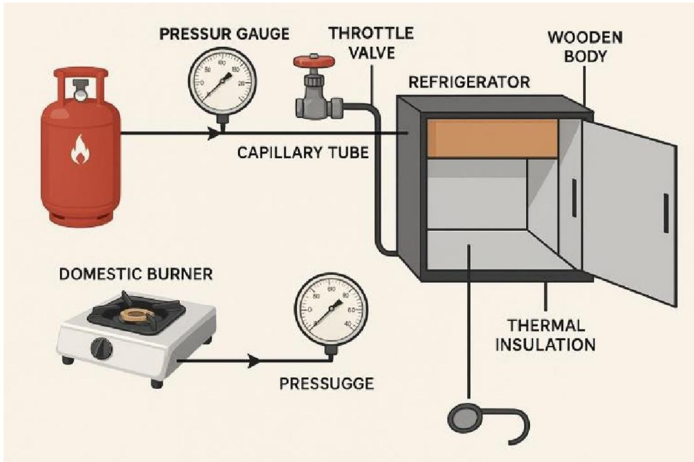
Electricity consumption is a major concern across the world, and in India, this issue is particularly pronounced in rural areas. These regions are significantly affected due to the lack of a stable and continuous electricity supply. Despite various efforts, the Indian government has not yet been able to ensure uninterrupted power access to all parts of the country. Refrigeration, however, is an essential need in both rural and urban areas. It is used for a wide range of purposes including the preservation of medicines, food storage in cold storage units, and daily use in domestic kitchens to prevent spoilage and maintain freshness.

LPG (liquefied petroleum gas) refrigerators offer a practical solution to this challenge, especially in areas with limited or no electricity. These refrigerators operate on a simple thermodynamic principle: when LPG, stored in liquid form, changes into its gaseous state, it undergoes expansion. This expansion process leads to a reduction in pressure and a simultaneous increase in volume. As pressure decreases, the temperature also drops, because temperature and pressure are directly related. This drop in temperature creates a cooling effect, known as the refrigerating effect, which is utilized to maintain low temperatures within the refrigerator. In addition to offering effective refrigeration without reliance on electricity, LPG refrigerators also contribute to environmental protection by reducing global warming potential [1].

II. MATERIALS AND METHOD

2.1 Materials

In this process, liquefied petroleum gas (LPG) is used as the refrigerant, acting as the primary cooling medium in the refrigerator. It serves as an alternative to conventional refrigerants, which are often more expensive and environmentally harmful. LPG offers a more economical and eco-friendly solution. The operation of the system is based on the fundamental principle of phase change: LPG, initially stored in its liquid state, undergoes a transformation into its gaseous form. During this phase change, the gas expands, resulting in a decrease in pressure and an increase in volume. As the pressure drops, the temperature also falls, due to the direct relationship between pressure and temperature. This reduction in temperature generates a cooling effect known as the refrigerating effect, which is harnessed within the refrigerator to maintain low internal temperatures suitable for preservation and storage purposes [2]



2.2 Methods

Liquefied Petroleum Gas (LPG) is a flammable hydrocarbon gas that is commonly used as a heating fuel in domestic applications. It is made by blending two primary gases: propane and butane. These two gases are combined in varying proportions to form LPG, which is then stored in liquid form under pressure. One of the main uses of LPG is as a fuel for heating, cooking, and refrigeration systems.

A critical component in LPG refrigeration systems is the capillary tube. This tube is made from copper, chosen for its excellent thermal conductivity and durability. The capillary tube has a very small internal diameter and is typically very long in length. The tube is coiled into several turns, which helps in saving space while allowing the refrigerant to expand and contract as it flows through the system. The pressure inside the capillary tube is determined by both the diameter and the length of the tube. The smaller the diameter, the higher the pressure, and the longer the tube, the more space it takes for the refrigerant to pass through.

The evaporator, another essential part of the refrigeration system, plays a vital role in the cooling process. It acts as a heat exchanger, transferring heat from the substance to be cooled into the refrigerant. The evaporator's size and shape can vary depending on the type of refrigeration system and its specific requirements. Evaporators are classified in several ways based on these variations, such as their function, design, or the type of cooling process they use.

In refrigeration systems, pressure gauges are often employed to monitor the pressure of the refrigerant within the system. A commonly used pressure gauge is the mechanical type, typically constructed from a metal tube that is flattened and bent into a circular shape. When fluid enters the tube, the internal pressure pushes the tube to either expand or contract. One end of the tube is fixed, while the other end moves in response to pressure changes. This movement helps in determining the pressure of the fluid inside the system, taking into account the difference between the internal fluid pressure and the outside atmospheric pressure.

In a refrigeration system, when a gas flows steadily through a constriction, such as an orifice or valve, it typically experiences a temperature change. This temperature change is partly due to a change in the gas's kinetic energy as it passes through the constriction. According to the first law of thermodynamics, this process is considered isenthalpic, meaning there is no change in the total enthalpy of the gas. The temperature change caused by the pressure drop can be quantified by the Joule-Thomson coefficient, which is defined as:

$$\mu JT = (\partial P/\partial T)H$$

This coefficient measures the change in temperature resulting from a drop in pressure across a constriction.

The Joule-Thomson process can be represented graphically using a Temperature-Pressure (T-P) diagram. In this diagram, the inversion curve is a crucial feature. The inversion curve separates the regions where the temperature behaves differently under a pressure drop. The region inside the curve where the Joule-Thomson coefficient (μ) is positive ($\mu > 0$) is known as the cooling region. In this region, the gas cools as it expands. The inversion point, where the Joule-Thomson coefficient equals zero ($\mu = 0$), represents the temperature at which the gas neither cools nor heats when expanding. On the other hand, the region where the Joule- Thomson coefficient is negative ($\mu < 0$) is called the heating region. In this region, the gas temperature increases as it expands. Thus, the Joule-Thomson effect helps in understanding how gases respond to pressure changes, which is critical in refrigeration processes where temperature control is essential.

III. CONCLUSION

From our observations, we have summarized that LPG (Liquefied Petroleum Gas) is typically stored in a cylinder at a high pressure of around 12.14 bar. The weight of this cylinder is approximately 14.5 kg. Among the various types of refrigerants, propane, which is a major component of LPG, is considered more eco-friendly compared to conventional refrigerants like CFCs (Chlorofluorocarbons). As such, propane has been increasingly used as an alternative to CFCs, particularly in refrigeration systems, due to its reduced environmental impact.

In refrigeration systems using a capillary tube, it has been observed that when the inner diameter of the capillary tube increases, the flow rate of the refrigerant also increases. This change in the geometry of the capillary tube has been found to improve the system's performance. Specifically, the increase in the coefficient of performance (COP) of the system is noticeable when the geometry of the capillary tube is altered. The COP is a measure of the efficiency of the refrigeration cycle, and an increase in COP means the system operates more efficiently, consuming less energy to achieve the same cooling effect.

Furthermore, research indicates that the COP of an LPG-based refrigerator is higher compared to refrigerators using R134a, another common refrigerant. The improvement in COP is significant, with LPG refrigerators outperforming those that use R134a by about 7.6%. In addition to this increased efficiency, the cooling capacity of an LPG refrigerator is reported to be 3 to 4 times greater than that of conventional refrigerants. This enhanced cooling performance further supports the idea that propane/butane mixtures, commonly found in LPG, are among the most promising alternatives for refrigeration systems.

LPG also offers significant environmental benefits as an alternative refrigerant. It helps in reducing both the ozone depletion potential (ODP) and the global warming potential (GWP) compared to traditional refrigerants like CFCs and HFCs (Hydrofluorocarbons). By using LPG as a refrigerant, we can mitigate some of the harmful environmental effects associated with older refrigerants, such as ozone layer depletion and global warming. This makes LPG a valuable and sustainable choice for the future of refrigeration technology.

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