EXPERIMENTAL INVESTIGATION OF THE POTENTIAL OF LIQUIFIED PETROLEUM GAS IN VAPOUR COMPRESSION REFRIGERATION SYSTEM

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ABSTRACT

The essence of refrigeration systems cannot be overemphasized especially in this part of the globe. Perishable items are to be preserved for some periods before usage while human comfort should also be also be paramount since we are in the northern hemisphere of the globe. The device hat doe this uses refrigerants as working fluids which are traditional harmful to human beings through depletion of the ozone layer. Majorly Ozone layer protects the earth from warming which could lead to flooding. Common economical refrigerants like CFCs (Chlorofluorocarbons) have been discovered to be harmful to the earth. This article therefore, experimented the quantity replacement of CFCs with Liquefied Petroleum Gas in various mixes. The LPG (Liquefied Petroleum Gas) used consists a mixture of propane and butane in the ratio 6:4 by mass. The blend of the two refrigerants were shaped essentially by blending at least two single-part refrigerants, the GWP (Global Warming Potentials) of a refrigerant mix is the mass-weighted normal of GWPs of individual parts in the mix. That is, to compute the GWP of a mix, one essentially adds the GWP of the singular parts with respect to their (GWP (LPG) x M (LPG)) + (GWP(R-134a) x M(R-134a)) = GWP (blend). From the evaluated GWP of the 6 different % mass composition, the % mass of (100%/0%) was the only refrigerant to adhere to the preferred GWP<150. The mass composition of blend (100%/0%) LPG/R-134a was first performed. In-order to achieve this, 8kg of each of the refrigerant was used. The blend was formed in an empty cylinder which was measured as 2482g with the aid of a digital beam balance, by gradually injecting LPG into the empty cylinder till the mass percentage of the 2000g entered, making the mass read as 4,482g (i.e., 2482g of the empty cylinder + 2000g of LPG). Based on the above observations, it could be inferred that the COP (Coefficient of Performance) of mixed refrigerants blends was higher than that of R-134a indicating that each of the blend exhibit higher performance. The experiment discovered that LPG could be used in the place of R134a without affecting the operation efficiency of a vapor compression refrigeration system. The study concludes that LPG offers the best alternative when the COP and flammability are combined as performance metrics

Keywords: *Refrigerant, Global Warming Potential, Vapor Compression, LPG, COP, Flammability*

INTRODUCTION

Refrigeration and air-conditioning play important roles in modern life. They are not only providing comfortable and healthy living environments, but have also come to be regarded as necessities for surviving severe weather and preserving food. In 2021 *Australian Government: Department of Agriculture, Water and the Environment* however, accelerated technical development and economic growth throughout the world during the last century have produced severed environmental problems, forcing us to acknowledge that though these technological advances may contribute to human comfort, they are also threatening the environment through ozone depletion and global warming (Boopathi,2019).Generally, refrigeration systems can be classified into 3 main cycle systems which are vapor compression refrigeration system, vapor absorption refrigeration system and gas cycle refrigeration system. According to Karamangil et all (2010), the most commonly used system in refrigeration and air-conditioning industry is vapor compression refrigeration system. According to Mohan, (2014), a considerable part of the energy produced worldwide is consumed by refrigerators and it is crucial to minimize the energy utilization of these devices. Vapor compression refrigeration system is a system in which a vapor known as the refrigerant is compressed, and then condensed with water or air, followed with expansion to a low pressure and correspondingly low temperature through a valve or an engine with a power takeoff i.e. the condenser Mani and Selladura (2008). The linkage of the Chlorofluorocarbon (CFC) refrigerants to the destruction of the ozone layer which has been recognized is attributable to their exceptional stability because of which they can survive in the atmosphere for decades, ultimately diffusing to the rarefied heights where the stratospheric ozone layer resides. The inventors of these refrigerants could not have visualized the ravaging effects of the refrigerants on the ozone layer (Dube, 2016). Today, the litany of the requirements imposed on an ideal refrigerant has increased. The additional primary requirements now include zero ozone depletion potential (ODP) and zero global warming potential (GWP). It is needful for the engineers to search for alternatives to CFC refrigerants, which will fulfill these new requirements in addition to the earlier primary requirements for the ideal refrigerants Oyelami and Bolaji. (2015). This paper analyses the processes of replacing conventional refrigerants with Liquefied Petroleum Gas (LPG) with zero ODP and lesser GWP. This is a mixture of commercial butane and commercial propane having both saturated and unsaturated hydrocarbons. LPG is a by-product of the refinery process of crude oil or natural gas. It consists mainly of propane (C_3H_8) and butane (C_4H_{10}) but may in contain some of the unsaturated component's propene (C_3H_6) and butene (C_4H_8). According to (Huth & Heilos, 2013)

State that the composition of LPG from its individual components is not fixed but has a typical ambient temperature, while the pressure of LPG is about 8 bars.

MATERIALS AND METHOD

Materials Needed

1. Serviceable refrigerator
2. Temperature Sensor
3. Pressure Gauge
4. Weighing scale
5. Liquefied Petroleum Gas (R600a)
6. R-134a

Refrigeration System

According to David (2010), 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 Rippon and Czajko (2019). Refrigerators and air conditioners both work on the principle of cooling through evaporation. Doohlinger (1993), described refrigerator which consists of two storage compartments – one for frozen items and the other for items requiring refrigeration but no freezing.

These compartments 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 Kinday and Parrish (2006). Coils surroundings the lower refrigerator compartment is 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, whre the entire cycle of pressurization, cooling and evaporation begins anew. Figure 1 provides a schematic diagram of the components of a typical vapor-compession refrigeration system.

Here is the various process of vapour compression cycle.

1) Compression: The vapour of refrigerants enters 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 shows the working evaporator in the refrigerator to carry out this experiment and it was tested to ensure that it is in a good condition before any further procedures. The two refrigerants needed was also used containing 8000g each of the refrigerant, that is, 8000g of LPG and R-134a respectively as shown in Fig.4. The weighing scale which is a digital weighing scale was used to measure the refrigerants before been charged into the compressor. Sample of the blends were allowed to leak out of the cylinder (compressor) into a flame and their flammability were observed as shown in Fig. 3. Fig. 5 shows the temperature sensor used was an infrared thermometer which made it possible to determine the temperature at different

points in the refrigerator system. The pressure gauge was used to check the pressure at the compressor.

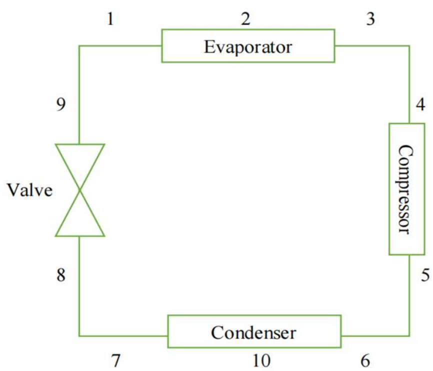

Fig 1: Schematic diagram of VCRS

Fig 2: A picture of the Evaporator in the refrigerator

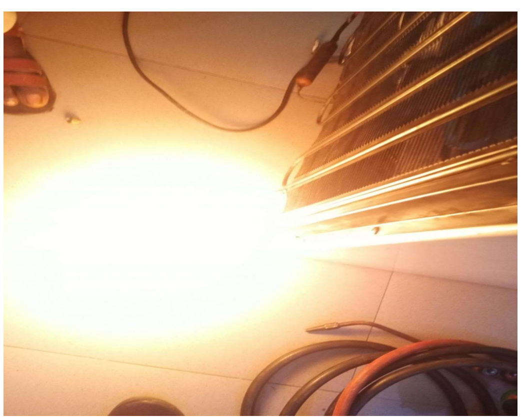

Fig 3: Picture showing the Flammability test by Ignition

Fig 4: Cylinder containing LPG refrigerant

Fig 5: obtaining temperature of the condenser using the infrared thermometer

RESULTS AND DISCUSION

Performance Parameters

Refrigeration Capacity

$$Q_{evap} = \dot{m}C_p\Delta T_{evap}Q_{evap} = \dot{m}C_p\Delta T_{evap} \quad (1)$$

$Q_{evap}Q_{evap}$ = Heat transfer of Evaporator in kW

$\dot{m}\dot{m}$ = Mass flow rate in kg/s

C_pC_p = Specific Heat Capacity in kJ/kg.K

$\Delta T_{evap}\Delta T_{evap}$ = Change in temperature of Evaporator in K

Coefficient of Performance

$$COP = \frac{T_{cond}-T_{evap}}{T_{cond}} COP = \frac{T_{cond}-T_{evap}}{T_{cond}} \quad (2)$$

$T_{cond} = Temperature\ of\ Condenser$ $T_{cond} = Temperature\ of\ Condenser$ in K

$T_{evap} = Temperature\ of\ Evaporator$ $T_{evap} = Temperature\ of\ Evaporator$ in K

Heat ejected by Condenser

$$Q_{cond} = \dot{m} C_p \Delta T_{cond} Q_{cond} = \dot{m} C_p \Delta T_{cond} \quad (3)$$

$Q_{cond} Q_{cond}$= Heat transfer of Condenser in kW

$\dot{m}\dot{m}$ = Mass flow rate in kg/s

$C_p C_p$ = Specific Heat Capacity in kJ/kg.K

$\Delta T_{cond} \Delta T_{cond}$ = Change in temperature of Condenser in K.

Table 1: Blended Refrigerant of LPG/R134a

TIME (mins)	EVAPORATOR TEMPERATURE (^{O}C)			COMPRESSOR TEMPERATURE (^{O}C)		CONDENSER TEMPERATURE (^{O}C)			EXPANSION VALVE TEMPERATURE (^{O}C)	
5	10.0	-7	13.0	14.3	26.5	32.4	32	25.5	30.2	33.0
10	18.3	-9	13.7	10.4	25.7	23.5	36	22.7	29.7	33.4
15	13.3	-7	10.5	13.5	27.5	26.4	40	24.1	28.9	31.3
20	9.6	-9	11.4	12.0	29.4	30.3	43	22.4	30.4	34.1
25	3.9	-10	9.4	11.5	30.6	33.4	46	27.5	29.8	33.7

Table 2: Coefficients of Performances (COP) of blended Refrigerant

BLENDS	COP (Coefficient of Performance)
100% LPG	1.283
20%/80% LPG/R134a	1.271
40%/60% LPG/R134a	1.298
80%/20% LPG/R134a	1.305
100% R134a	0.800
60%/40% LPG/R134a	1.296

This research has experimented the use of alternative refrigerant as working fluids in refrigeration systems. Refrigeration is a process to transfer heat from the objects for cooling and freezing for maintaining the temperature of surroundings for preservation purposes and comfort. Refrigerants are the materials or working fluids use in air-conditioning and refrigeration system. Therefore, the following tables consist of all experimental results carried out on the performance evaluation vapor compression refrigeration system.

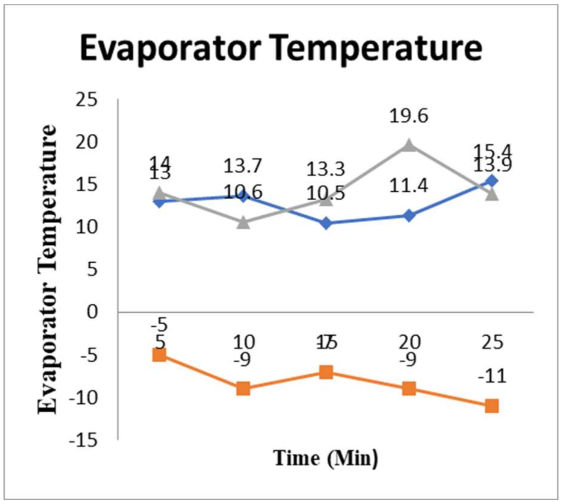

Fig. 6. Variation of Evaporator Temperature Coefficient of Performance

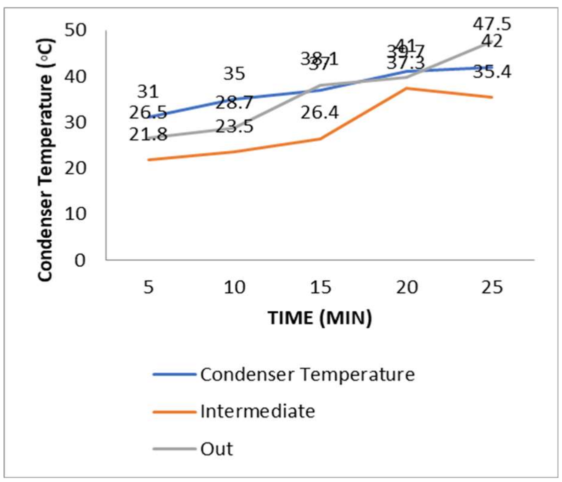

Fig. 7: Variation of Condenser Temperature with Time at an Ambient Temperature of 32°

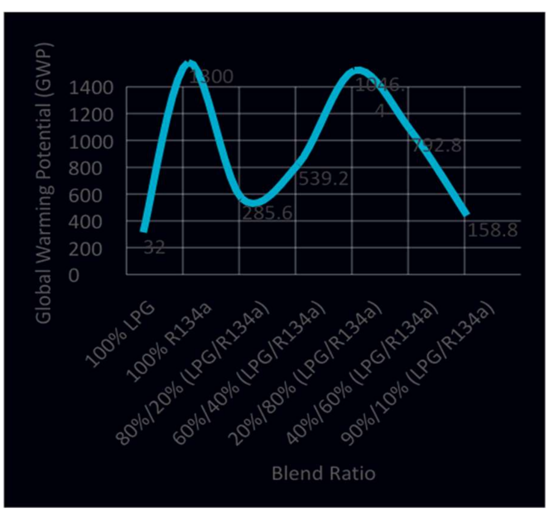

Fig. 8: Global Warming Potential with Time at an Ambient Temperature of 32°C

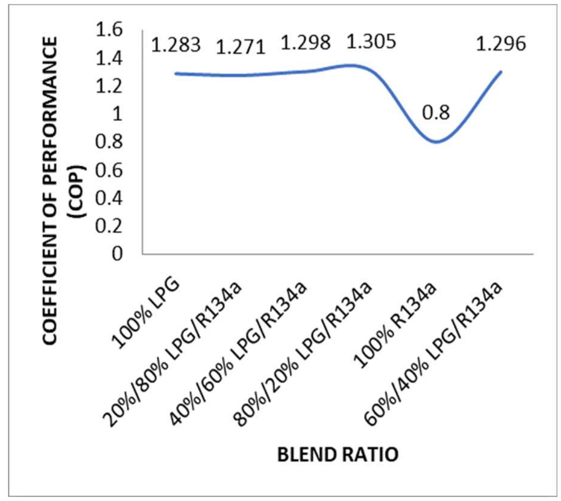

Fig. 9: Variation of COP with Time at an Ambient Temperature of 32°C

The obtained data agreed well with each other's giving an indication of reliability on the setup to be used when comparing the different refrigerant fluids. Table 1 and table 2 shows the 100-percentage mass composition of R134a refrigerant and LPG as alternative refrigerant respectively. Analysis of the results as presented in Fig. 6 to 9 shows the performances of blended refrigerants. In fig. 9 the difference in COP is due to the ability of the blends to attained different evaporator and condenser temperatures based on the above observations as shown in figs. 7 and 8, it could be inferred that the COP of the formulated refrigerants blends is higher than that of R-134a indicating that each of the blend exhibit higher performance. Therefore, the LPG could be used in the place of R134a without affecting the operation efficiency of a vapor compression refrigeration system. It could also be observed from this study that LPG offers the best alternative when the COP and flammability are combined as performance metrics. This is because it has higher COP (1.300; 1.283) as shown in fig. 8 compared to R-134a (0.800; 0.767) at ambient temperatures of 32°C respectively with GWP of 32 to 1300.

CONCLUSION

After completion of the investigation, it was observed and noted that refrigeration effect is produced with the use of LPG. And that, the COP of the formulated refrigerants blends was higher than that of R-134a indicating that each of the blend exhibit higher performance. Therefore, the LPG could be used in the place of R134a without affecting the operational efficiency of a vapour compression refrigeration system. It was also observed that LPG offers the best alternative

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