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Research Article

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Performance of Liquefied Petroleum Gas (LPG) as Refrigerant in a Vapour Compression System

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Abstract The basis for parameters adapted for this work include the refrigerating capacity and compressor power against the evaporator temperature, the refrigerating capacity and compressor power against the condenser temperature, as well as the COP against the evaporator temperature. The constituent of the LPG used was propane and butane in the ratio 60/40% by mass. The mean average value was adopted after carrying out each test for three times, at various ambient temperatures, producing average ambient temperatures ranging from 27.5 to 33.5℃, which developed evaporator temperatures ranging from -13.0 to -3.0℃ and condenser temperature, ranging from 28 to 40℃ respectively. A steady-state process design and operational analysis simulation software, SIMSCI/PROII, was used to determine the enthalpy values for LPG refrigerant. The values obtained were then used to calculate important performance parameters including coefficient of performance, refrigeration effect and compressor power.

Keywords Refrigerant, LPG, Chlorofluorocarbons (CFC), Global Warming Potential (GWP)

Introduction

Refrigerant is defined as a heat transfer medium (or working fluid) in vapour compression refrigeration system, which absorbs heat through evaporation and rejects heat through condensation. The refrigerant undergoes physical change but the chemical situation remains the same. It only alternately vaporizes from the liquid state (to absorb the heat in the evaporator) and condenses to its liquid state (for reuse in the evaporator) by rejecting to the surroundings its superheat and latent heat of vaporization through condenser. The effective running of a vapour compression system, to a large extent, depends on the installation and services, by the service Engineer. To this effect, effective efforts had been made in the educational sector, to give service Engineers the best and even much more is coming. Engineers in this field needs to be updated effectively, as new inventions and discoveries are coming up in mechanical and technical areas of this field, thus Engineers in the field needs to be abreast of happenings to be effective [1].

We have Primary refrigerants and secondary refrigerants. Refrigerants which are used directly in a pour compression system are the primary refrigerants while secondary refrigerants are first cooled by primary refrigerants and then used for imparting refrigeration [1].

The American Household Appliances Manufacturers (AHAM) has identified some hydro fluorocarbon (HFC) refrigerants such as R134a and R152a as better replacement for R12 in domestic refrigerators. These refrigerants were commonly used due to their superior stability and safety properties: they are non-flammable and non-toxic as the fluids they replaced [2]. However, these chlorine-bearing refrigerants (CFCs) reach the upper atmosphere when they escape and in the stratosphere, CFCs break up due to UV-radiation, releasing their chlorine atoms. These chlorine atoms act as catalysts in the breakdown of ozone, thus causing severe damage to the ozone layer that shields the Earth's surface from the Sun's strong UV radiation [3-4]. The chlorine will remain active as a catalyst until and unless it binds with another particle, forming a stable molecule. Newer refrigerants that have reduced ozone depletion effect include HCFCs (e.g. R22, used in most homes today and R23 used in industrial chillers). HCFCs in turn are being phased out under the Montreal Protocol and replaced by hydro-fluorocarbons (HFCs), such as R134a, R407C and R410A which lack chlorine. However, CFCs, HCFCs, and HFCs all have higher global warming potentials.

Hydrocarbons generally have their ozone depletion potential to be zero and their green house effect considered insignificant compared with R12. They have very good physical, chemical and thermodynamic properties. The present working fluids in the existing vapour compression refrigerating systems are CFC, HCFC and HFC refrigerants. Different sectors are challenged to find suitable alternatives. Appliance energy standards, designed to contain the global warming effects, is another major challenge facing the refrigeration industry. Thus the need for a suitable, efficient and more environmentally friendly working fluid to replace the existing working fluid in vapour compression refrigerating systems. In searching for a suitable refrigerant, the performance of Liquefied Petroleum Gas (LPG) was investigated experimentally in a vapour compression refrigeration system and compared with R134a [5].

Liquefied Petroleum Gas (LPG) is a flammable mixture of hydrocarbon gases used as a fuel in heating appliances and vehicles. It is increasingly used as an aerosol propellant and a refrigerant, replacing chlorofluorocarbons in an effort to reduce damage to the ozone layer. Varieties of LPG available include mixtures that are primarily propane C_3H_8 and butane C_4H_{10}, depending on the season — in winter more propane, in summer more butane. Propylene and butylenes are usually also present in small concentration. A powerful odorant, ethanethiol, is added so that leaks can be detected easily. In the United States, thiophene or amyl mercaptan is also approved odorants. LPG is a low-carbon-emitting hydrocarbon fuel available locally, emitting 81% of the CO_2 per kWh produced by oil, 70% of that of coal, and less than 50% of that emitted by coal-generated electricity distributed via the grid. Being a mix of propane and butane, LPG emits less carbon per joule than butane but more carbon per joule than propane [6].

Experimental Procedure

The performance parameters, such as refrigerating capacity and compressor power versus the evaporator temperature, the refrigerating capacity and compressor power versus the condenser temperature, as well as the COP versus the evaporator temperature, After extracting the enthalpy values for each, important performance parameters, such as refrigeration capacity (Q_{evap}), compressor power ($\dot{W}_C$), coefficient of performance (COP) and pressure ratio (Pr) were evaluated using the following equations:

- Refrigeration capacity, $Q_{evap} = \dot{m}\,(h_1 - h_4)$ (kW) (1)

  Where: $\dot{m}$ = mass flow rate (kg/s); $h_1 - h_4$ = refrigerating effect of refrigerant (kJ/kg)
- Power requirement of compressor:

  The compressor power consumption, $\dot{W}_c = \dot{m}(h_2 - h_1)$ (W) (2)

  Compressor pressure ratio, (P_R) is given as: $P_R = \frac{P_{dis}}{P_{suc}}$ (3)

  Where: P_{dis} = compressor discharge pressure (bar)
  P_{suc} = compressor suction pressure (bar)
- Coefficient of Performance, $COP = \frac{Q_{evap}}{\dot{W}_c}$ (4)
- Heat ejected by Condenser, $Q_{cond} = \dot{m}\,(h_2 - h_3)$ (kW) (5)

For LPG system, obtaining thermodynamic properties (like the enthalpy and entropy) of LPG at steady state needs the use of special computer software for simulation, because LPG has different compositions.

0.05kg of LPG with composition 40% of butane and 60% of propane was charged into the system with the help of charging system. The mercury thermometer, thermocouples and a pressure measuring device, also a special temperature gauge called Athermeter, with a wide range of - 40 to + 40, and accuracy value of ±0.05 dedicated for taking the evaporator readings, with the probe protruding to the refrigerating space through a drill on the cooler. The output of these sensors was recorded. The temperature and pressure readings were taken at an interval of 45 minutes at the inlet and outlet of various units, three times daily for five days, random selection at different ambient temperature of all this was used for this experimental investigation. The values obtained from the readings were feed and ran in the simulator, SIMSCI/PROII software to determine the enthalpy of the refrigerant, to obtain the thermodynamic properties of LPG. The readings were then used obtaining parameters such as the refrigeration capacity (Q_e), compressor power ($\dot{W}_c$), and the coefficient of performance (COP) All equipment and test unit was placed under different environmental conditions, (ambient temperature) at the same time. The ambient temperatures range from 27.5 to 33.5℃. When the temperature and humidity under each condition was at steady state, the experiments started.

Results and Discussion

The graphs of the refrigerating capacity and compressor power versus the evaporator temperature, the refrigerating capacity and compressor power versus the condenser temperature, as well as the COP versus the evaporator temperature were ploted

Fig 1 shows the refrigerating capacity and compressor power increases as Te increases. This is due to high enthalpy values of saturated vapour leaving the evaporator as Te increases.

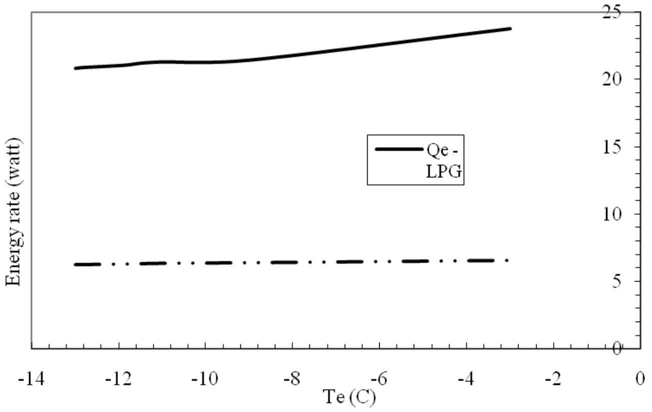

Figure 1: Refrigerating capacity (Qe) and compressor power (W) versus Te

Fig 2 shows that COP increases as Te increases, Since the coefficient of performance is determined by dividing Qe by Wc, COP reached a value of 3.6 at Te = -3°C. This value is compared to the results of Wong and Chimres (2005).

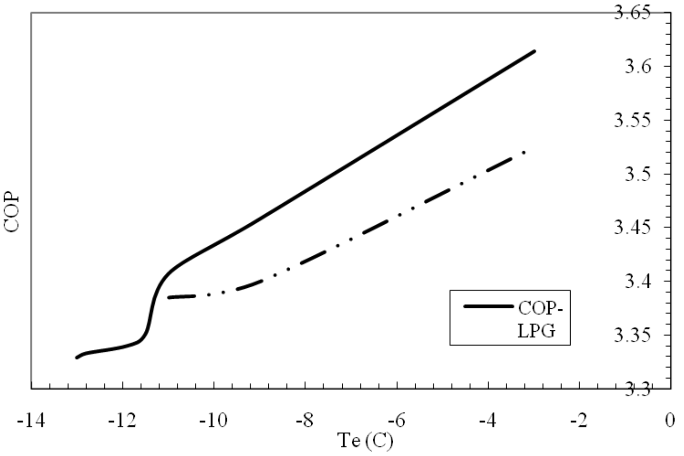

Figure 2: Coefficent of Performance (COP) versus Te

Fig 3 shows the variation of Qe and Wc with respect to Tc. Increasing Tc causes Qe and Wc to decrease.

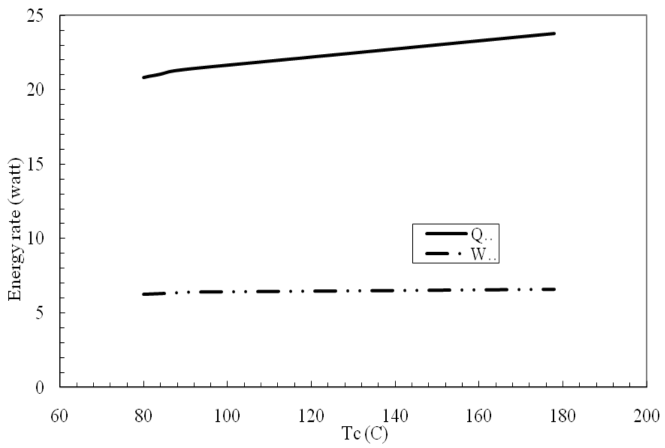

Figure 3: Refrigerating capacity (Qe) and compressor power (W) versus Tc

The refrigerating capacity Qe for Te and Tc tests was obtained by calculating the heat removal rate from the water load when placed in the cooler.

The LPG mass flow rate, m is obtained by dividing the quantity of gas charged in the compressor (0.05kg) by the time taken for the charging process (1s). i.e 0.05/1 =0.05kg/s.

The British standard institutions published by ACRIB [6] allow the use of LPG as refrigerant if small amount of refrigerant is required. This has been justified, in this work, by the high performance of a very low amount of LPG refrigerant charged into the system, the use of LPG add values to the effect of the compressor as well as the refrigerating effect, it also increase the coefficient of performance of the equipment, which also coincide with the work of Wong and Chimres (2005). LPG refrigerant can be successfully adopted as R134a substitute in vapour compression refrigerating system [5].

It is recommended that in using LPG refrigerant, the allowable refrigerant charge, flammability properties, safety standard and codes must be taken into consideration. The limiting factors associated with the use of hydrocarbon refrigerants are the refrigerant charge size, the occupancy category and the room size. It is also recommended that workshops and seminars should be organized for the technicians on the need to embrace the use of LPG refrigerant [5].

References

[1]. Oyelami S., and Bolaji, B., (2015) Experimental investigation of the performance of liquefied petroleum gas (LPG) refrigerant in a vapour compression refrigeration system. *International Journal of Scientific & Engineering research* Volume 6, Issue 6.

[2]. David L. (2010) Fundamentals of refrigeration. Free education on the internet, http:/www.free-ed.net.

[3]. Doohlinger, M. (1993) Comparative Energy Efficiencies of Hydrocarbon Refrigerants, Ozone Safe Cooling Conference, Washington DC.

[4]. MacKenzie, D., (1994) Fridge maker freezes out CFC substitute, *New Scientist, 5th February, p. 4. Germany.*

[5]. Oyelami S., and Bolaji, B., (2016) Design and construction of a vapour compression refrigeration system as test rig to investigate the performance of liquefied petroleum gas (LPG) as refrigerant. *Journal of Scientific and Engineering Research*, 3(4):350-357.

[6]. ACRIB (2001) Guildlines for the use of Hydrocarbon Refrigerants in Static Refrigeration and Air Conditioning Systems. Vol 1.http:/ www.acrib.org.uk