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Experimental studies on the effect of magnetic field in energy consumption using R134a, LPG and LPG/R134a mixture as substitutes for CFC 12 systems

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Abstract

This paper presents an experimental study on the performance of environmentally friendly refrigerants such as R134a, LPG and LPG/R134a mixture with and without the effect of magnetic field as suitable replacements for the refrigerant R12 in a vapour compression refrigeration system. Experimental results with no magnets showed that the LPG/R134a mixture had 6.5% higher refrigerating capacity than that of R134a and 4.2% lower than R12 for higher evaporating temperatures. The LPG/R134a mixture had lower refrigerating capacity than that of R12 and R134a at lower evaporating temperatures. The coefficient performance of LPG/R134a mixture increased from 2.6% to 5.9% than R12 at higher evaporating temperatures while decreased from 6.4% to 30.4% at lower evaporating temperatures. The compressor power consumption of LPG/R134a mixture was reduced from 2.5% to 10.3% than that of R12 for all the range of operating conditions. The refrigerating effect, COP and power consumption of LPG was lower than that of R12, R134a and LPG/R134a mixture.

Experimental results with the effect of magnetic field force showed that the compressor consumed 1.6 – 2.1% less energy than with no magnets. The behaviour of refrigerants varies from one refrigerant to another depending upon the mixture's composition and its boiling point. The effect of magnetic field force increased coefficient of performance of the system in the range 0.15 – 1.7%. There was no significant influence in the thermal capacities of the condenser and evaporator, discharge pressure and temperature of these selected refrigerants under magnetic field. The LPG/R134 (60/40 by wt.%) mixture can be considered as an excellent alternative refrigerant in CFC12 system. LPG can be considered as an alternative refrigerant for higher evaporating temperatures in a CFC12 system.

Keywords: LPG; LPG/R134a mixture; alternative refrigerants; ODP; global warming; magnetic field.

Introduction

The refrigerants chlorofluorocarbon (CFCs) and hydrochlorofluorocarbon (HCFCs) both have high ozone depleting potential (ODP) and global warming potential (GWP) and contributes to ozone layer depletion and global warming. Therefore these two refrigerants are required to be replaced with environmentally friendly refrigerants to protect the environment. The hydrofluorocarbon (HFC) refrigerants with zero ozone depletion potential have been recommended as alternatives. R134a is the long-term replacement refrigerant for R12 because of having favourable characteristics such as zero ODP, non-flammability, stability and similar vapour pressure as that of R12 [1-3]. The ODP of R134a is zero, but it has a relatively high global warming potential. Many studies are being carried out which are concentrating on the application of environmentally friendly refrigerants in refrigeration systems. Hydrocarbon (HC) refrigerants have zero ODP and negligible GWP. From thermodynamic point of view, some hydrocarbon refrigerants are good alternatives.

In this work the liquefied petroleum gas (LPG) mixture and LPG /R134a (60/40 by wt. %) were studied in a vapour compression refrigeration system with and without the effect of magnetic field force and compared with R12 and R134a. The LPG is locally and commercially available at a cheaper rate than both R12 and R134a.The study was carried over a wider range of evaporating and condensing temperatures for a range of applications.

The main constituent in LPG are propane, n-butane and isobutane, its contents may vary from one source to another and from one country to another The LPG was obtained for this experiment from local suppliers in India. The range of composition of the LPG supplied by the petroleum corporation in India by liquid volume percentage was: propane, 25%-45%; n-butane, 45% - 55%; iso-butane, 5% - 20%; ethane and unsaturated hydrocarbon, 2%.

Magnetic refrigeration is an environmentally friendly cooling technology. It does not use ozone-depleting chemical (such as CFCs), hazardous chemicals (such as NH_3) and green house gases (HCFCs and HFCs). Some magnetic materials heat up when they are placed in a magnetic field and cool down when they are removed from a magnetic field. This is known as magneto caloric effect. Several studies have been reported on the use of magnetic elements in enhancing the performance in many applications such as oil, natural gas furnaces, diesel engines, fuel lines and in water treatment.

Gschneidddner and Pecharsky [4] reported the magnetic caloric effect and its application for cooling near room temperature. They also reported the relationship between the nature of magnetic transformation and the temperature dependence of the magnet caloric effect and the entropy utilized in the magneto-caloric. Foldeaki et al. [5] presented the magnetic measurements to evaluate the thermodynamic behaviour of magnetic materials. Samuel M.Sami and Shawn Aucoin [6] presented the test results of the performance of new alternative refrigerants such as R 410A, R 507, R 407C and R 404A under various conditions of magnetic field. They reported that the increase in magnetic field force, increases compressor head pressure and discharge temperature slightly as well as less liquid refrigerant is boiling in the compressor shell. They also reported that the increase in the magnetic field force enhances the COP of the system.

Samuel M.Sami and R.J.Kitta [7] presented the test results of the performance of new alternative refrigerants such as R 410A, R 507, R 407C and R 404A under various conditions of magnetic field. They reported that the effect of magnetic field on refrigerant mixture varies from one mixture to another depending upon the mixture's composition, boiling point and thermo physical properties. They also reported that the use of magnetic field have influence on thermal capacities of the condenser and evaporator.

Richard et al [8] reported that in a magnetic refrigerator multimaterial regenerator was found to produce a higher temperature span and more cooling power than the single material regenerator under certain operating conditions.

To the authors knowledge except Sami et al. none have been reported on the refrigerants behaviour under the effect of magnetic field. The experiments were carried out with and without the effect of magnetic field using the refrigerants CFC12, HFC134a, LPG and LPG/R134a (60/40 by wt. %) and their results were compared.

Experimental apparatus

An experimental setup of vapour compression refrigeration system was built up to investigate the performance R12, R134a, LPG and LPG/R134a (60/40 by wt.%) mixture refrigerants. Fig.1 shows the schematic diagram of the experimental setup. It consists of two loops; Main loop and secondary loops. The main loop was composed of compressor, condenser, a filter-drier, refrigerant flow meter, sight glass, expansion valve and evaporator. The compressor was an open, reciprocating type. The rotating speed of the compressor was 855 rpm and its speed could be changed by a variable diameter belt pulley of the electrical motor.

The condenser and evaporator are of both copper double tubes. In the double tube condenser, the refrigerant flows through the inner tube while the cooling water flows through the annular space between the inner and outer tubes. In the double tube evaporator the brine solution (calcium chloride/water solution) flows through the inner tube and the refrigerant flows through the annular space between them. For minimizing the heat loss, the outer tube was well insulated. Two sight glasses were incorporated into the system, one in the liquid line at the condenser outlet and another in the vapour line at the evaporator outlet in order to give a visual indication of the refrigerant circulation.

The secondary loops were composed of a pump, a flow meter and an electrically heated unit within the insulated tank. One tank was filled with cooling water and circulated through the condenser tubes while the other tank was filled with brine solution and circulated through the evaporator tubes. The hot water coming out of the condenser tube was supplied to a cooling tower and gets cooled. This cooled water again pumped to the condenser cooling water tank through a separate pump.

Six magnetic elements with Gauss level of 4000 each have been employed in this study. The dimensions of the magnets are 2.5x2.5x1 cm. These magnets were placed on the refrigerant full liquid line at condenser outlet. This is confirmed by observation through the sight glass.

Experimental procedure

The main objective of this study is to study the compressor energy consumption and system coefficient of performance with and without the effect of magnetic field.
Rotameters were used to measure the flow rates of the cooling water and brine solution. The refrigerant flow meter was used to measure the refrigerant flow rate with an accuracy of ±3% in the range of the reading. RTD type thermocouples were used to measure the temperatures with an accuracy of ±0.1% and pressures were measured using calibrated pressure gauges with an accuracy of ±1% of the reading used.

The temperatures and pressures of the refrigerant and secondary fluid temperatures were measured at various locations in the experimental setup as shown in fig.1. The compressor power consumption was measured using a wattmeter. An expansion device was used to regulate the mass flow rate of refrigerant and to set pressure difference.

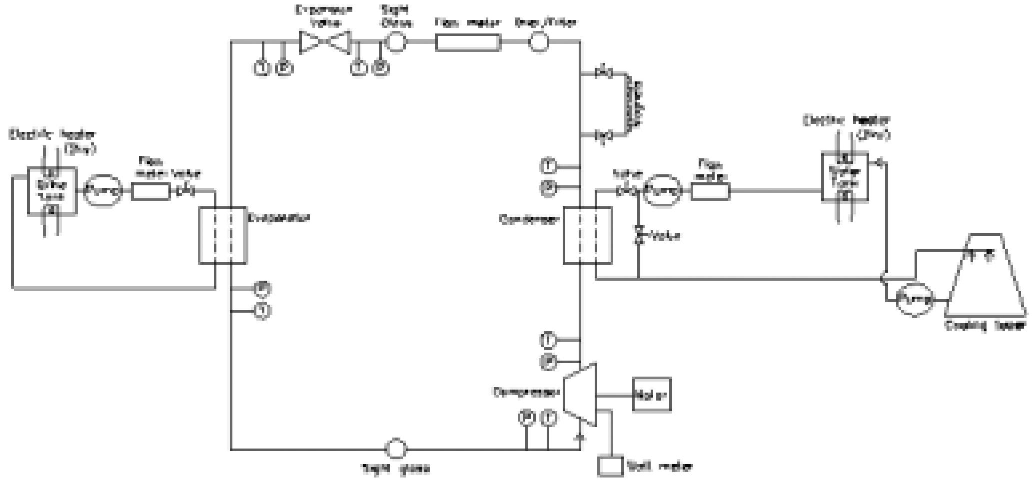

Figure 1: Schematic diagram of the experimental setup

The refrigerant was charged after the system had been evacuated. The working fluids were R12, R134a, LPG and LPG/R134a (60/40 by wt.%). Drop-in experiments were carried out without any modification to the experimental apparatus. The experiment was started with R12 to set up the base reference for further comparisons with the other three refrigerants. The desired evaporating and condensing temperatures were obtained by adjusting all the other parameters in the system such as cooling water flow rate and its temperature, refrigerant flow rate and brine solution flow rate and its temperature. The thermodynamic properties of the refrigerants were taken from the NIST [9] REFPROP database. The readings were taken after the system had reached steady state conditions.

Results and discussion

The results of the various refrigerants with no magnets were used as a baseline for this study. When test with one particular refrigerant was completed, the system was evacuated and then recharged with the preferred refrigerant. This procedure was followed for every alternative refrigerant.

Refrigerating capacity

The figures 2 and 3 shows the variations of refrigerating capacity against evaporating temperature for the condensing temperatures of 35°C, and 45°C respectively with no magnets. It was observed that R12 had the highest refrigerating capacity than R134a, LPG and LPG/R134a mixture. The refrigerating capacity of LPG/R134a mixture was 3.1% - 6.5% higher for the higher evaporating temperatures and 30.5% - 32.1% lower for the lower evaporating temperatures than R134a with no magnets. For a condensing temperature of 45°C, the LPG/R134a mixture showed 2.3% - 6.5% high refrigerating capacity than R134a for all operating conditions. The LPG/R134a mixture showed lower refrigerating capacity than R12. The refrigerating capacity of LPG/R134a mixture was very close to R12 for a condensing temperature of 45°C as shown in Fig.4. LPG showed lower refrigerating capacity than R12, R134a and LPG/R134a mixture for all the operating conditions. There was no significant change in the thermal capacities of the evaporator.

Compressor energy consumption

The figures 4 and 5 shows that the energy consumed by the compressor against evaporating temperatures with and without the effect of magnetic field. The system with refrigerant R12 consumed highest energy while LPG consumed lowest energy. The system with LPG/R134a (60/40 by wt %) mixture consumed 2.5% - 10.3% less energy with no magnets than that with R12 over the whole range of operating conditions. The refrigerant R134a consumed more energy than that of LPG/R134a mixture. Experimental results with the effect of magnetic field force showed that the compressor consumed 1.6 – 2.1% less energy than with no magnets for all the operating conditions. The behaviour of refrigerants varies from one refrigerant to another depending upon the mixture's composition and its boiling point.

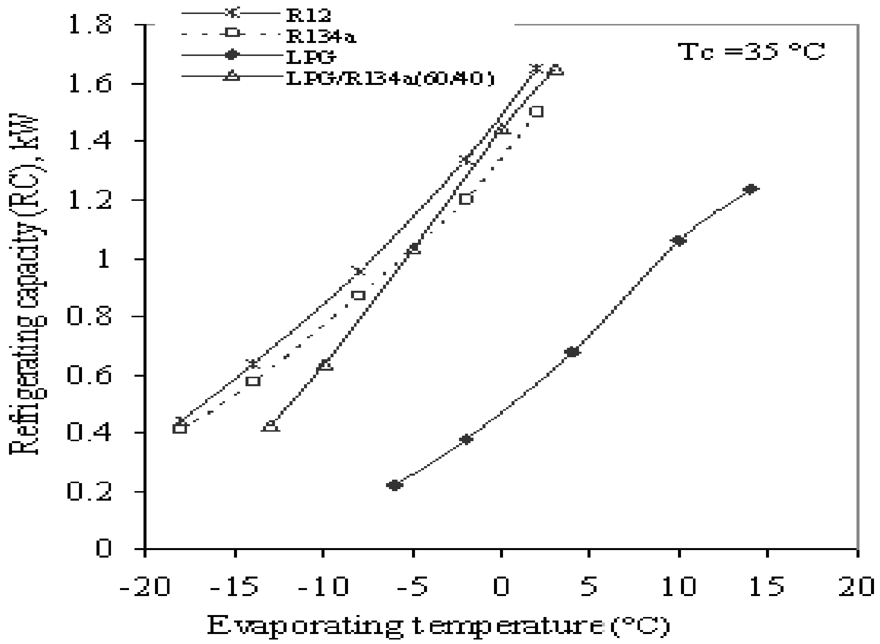

Figure 2: RC vs Evaporating temperature for a condensing temperature of 35^0C

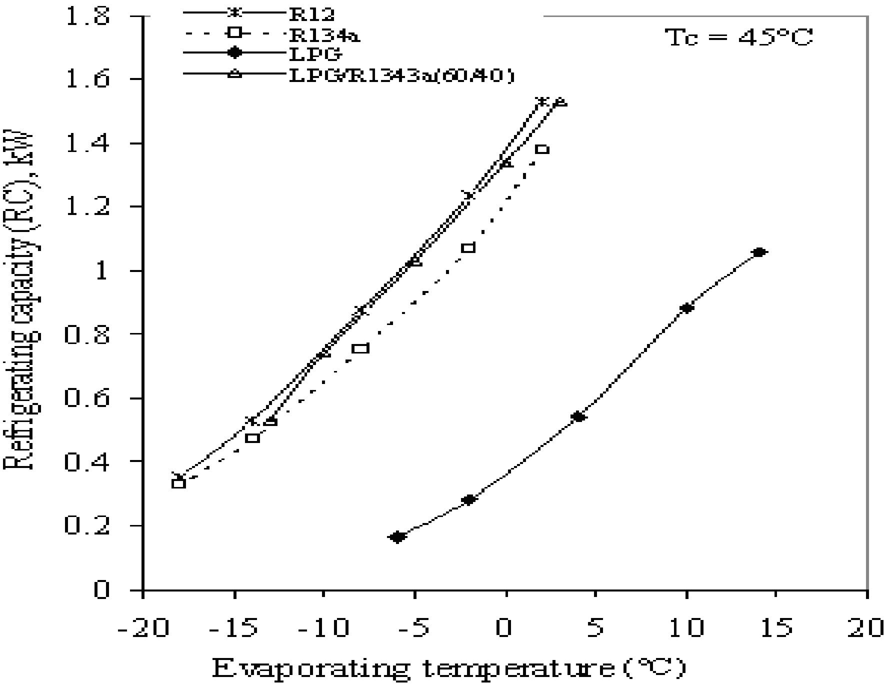

Figure 3: RC vs Evaporating temperature for a condensing temperature of 45^0C

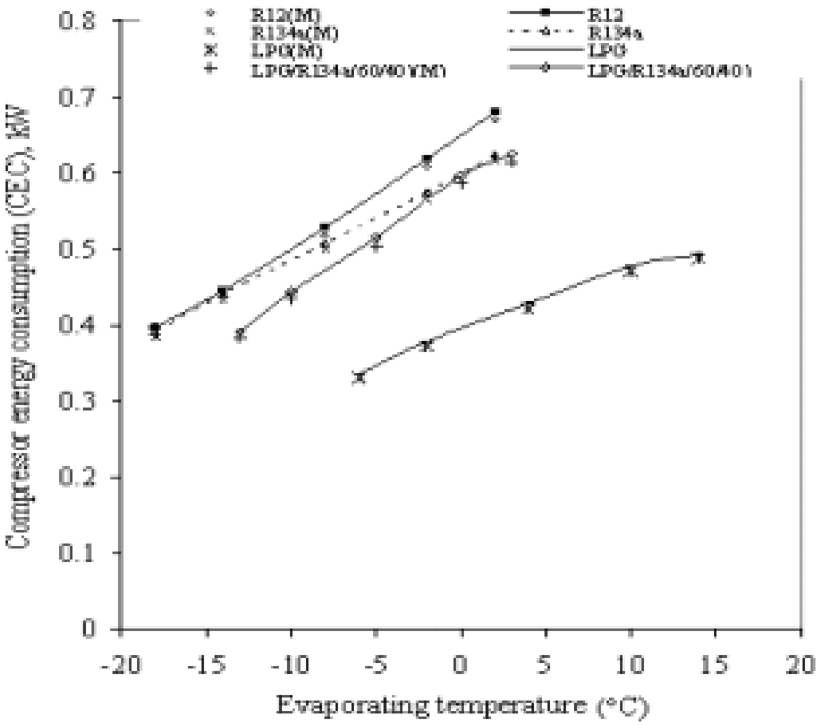

Figure 4: CEC vs Evaporating temperature with and without magnets for Tc =35^{0}C

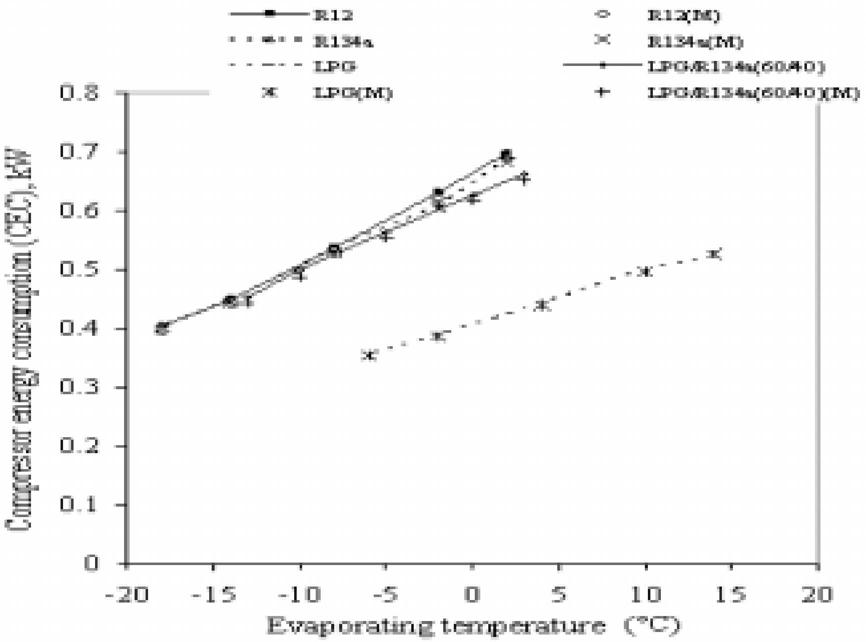

Fig.5. CEC vs Evaporating temperature with and without magnet for Tc = 45 °C

Figure 5: CEC vs Evaporating temperature with and without magnet for Tc=45^{0}C

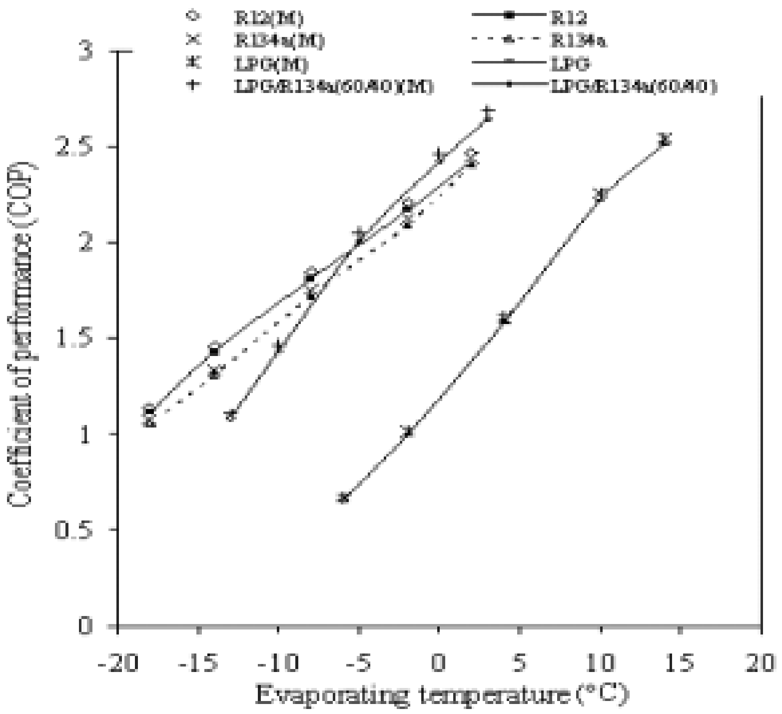

Figure 6: COP vs Evaporating temperature with and without magnet for Tc = 35^0C

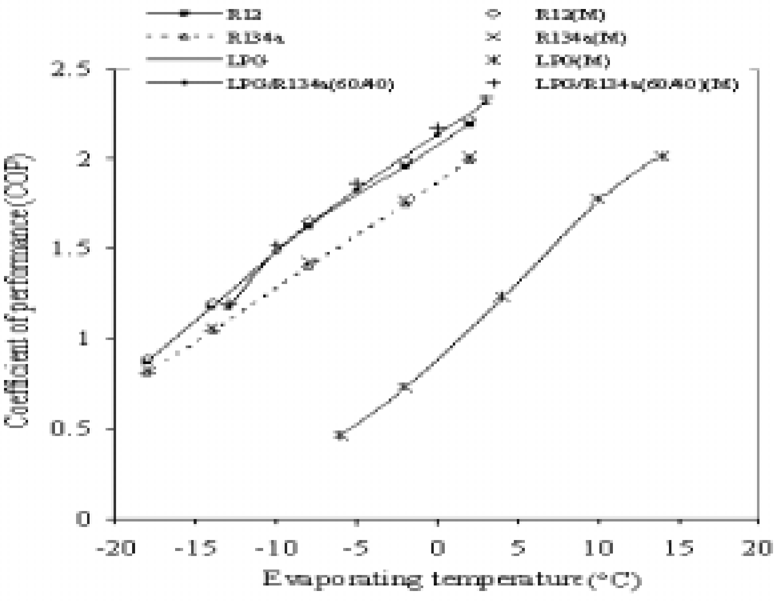

Figure 7: COP vs Evaporating temperature with and without magnet for Tc = 45^0C

Coefficient of performance

The figures 6 and 7 shows the coefficient of performance for R12, R134a, LPG and LPG/R134a (60/40 by wt %) mixture for various evaporating temperatures with condensing temperatures of 35°C and 45°C respectively with and without magnetic field effect. It was observed that the COP with LPG/R134a (60/40 by wt %) mixture was 7.7 – 12.9% higher than R134a and 2.6 – 5.9% higher than R12 for the higher evaporating temperatures while 21.2 – 24% lower than R134a and 6.4 – 30.4% lower than R12 for the lower evaporating temperatures with no magnets. The COP of the LPG/R134a (60/40 by wt %) mixture was 6 – 12.9% higher than R134a for all evaporating temperatures at a condensing temperature of 45°C as shown in Fig.7. LPG showed lower COP for all operating conditions. The effect of magnetic field force increased coefficient of performance of the system in the range 0.15 – 1.7% for all the operating conditions.

Conclusions

During the experimental study on vapour compression refrigeration system, the performance of these new substitutes under the effect of magnetic field force were investigated and compared to that of no magnet condition.

(1) Refrigerating capacity of LPG/R134a (60/40) mixture was 6.5% more than R134a and 4.2% less than R12 at higher evaporating temperatures while lower than R12 and R134a at lower evaporating temperatures with no magnets. There was no significant influence of magnetic field force on the refrigerating capacity.

(2) The COP of LPG/R134a (60/40) mixture was higher in the range 0.15 – 1.7% with magnetic field force for all the operating conditions compared to that with no magnets. The COP of the LPG/R134a (60/40) mixture was 6 – 12.9% higher than R134a for all evaporating temperatures at the condensing temperature of 45°C with no magnets.

(3) The power consumed by LPG/R134a (60/40) mixture was lower in the range 1.6 – 2.1% for all the operating conditions compared to that with no magnets.

(4) The magnetic field force had no significant influence on discharge temperature and discharge pressure for all operating conditions.

(5) The LPG showed low refrigerating capacity, COP and energy consumption than R12, R134a and LPG/R134a (60/40) mixture with and without the effect of field force for all operating conditions.

During the operation of the test apparatus LPG and LPG/R134a (60/40) mixture were found to be safe when appropriate operational procedures were followed. However care should be taken when using LPG and LPG/R134a (60/40) mixture in a refrigeration/heat pump system. From the environmental impact and energy savings point of view, the LPG/R134a (60/40 by wt.%) mixture can be considered as an alternative refrigerant for CFC12 systems. LPG can be considered for a range of applications at higher evaporating temperatures.

Abbreviations

CFC	chlorofluoroca
HCFC	hydrochlorofluorocarbon
HFC	hydrofluorocarbon
HC	hydrocarbon
ODP	ozone depletion potential
GWP	global warming potential
GTD	gliding temperature difference (°C)
RC	refrigeration capacity (kW)
COP	coefficient of performance
CPC	compressor power consumption (kW)

List of symbols

c	condensing/ condenser

References

[1] UNEP., 1987, “Montreal Protocol on substances that deplete the ozone layer, final act,” New York, United Nations Environmental Program.

[2] David Butler., 2001, “Life after CFCs and HCFCs,” CIBSE National Conference.

[3] Devotta, S., Gopichand, S., 1992, “Comparative assessment of HFC 134a and some refrigerants as alternatives to CFC 1,” International Journal of Refrigeration 15(2), pp. 112-118.

[4] Gschneidddner, KA., Pecharsky, VK., 1999, “Magnetic refrigeration materials,” Journalof Applied Physics, 85(8), pp 5365-5368.

[5] Foldeaki, M., Chahine, R.,Bose, TK.,1995, “Magnetic measurements: A powerful tool in magnetic refrigerator design,” Journal of Applied Physics, 77(7), pp. 3528- 3537.

[6] Sami, SM., Aucoin, S., 2003, “Effect of magnetic field on the performance of new refrigerant mixtures,” International Journal of Energy Research, 27, pp. 203-214.

[7] Sami, SM., Kita, RJ., 2005, “Behaviour of new refrigerant mixtures under magnetic field,” International Journal of Energy Research, 29, pp.1205-1213.

[8] Richard, MA., Rowe, AM., Chahine, R., 2004, “Magnetic refrigeration: Singleand miltimaterial active magnetic regenerator experiments,” Journal of Applied Physics, 95(4), pp. 2146-2150.

[9] “Thermodynamic properties of refrigerants and refrigerant mixtures,” NIST Standard Reference Database, version 7.0., Gaithersburg.